ESERA SUMMER SCHOOL 2016

BOOK OF SYNOPSIS

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v Českých Budějovicích
University of South Bohemia
in České Budějovice

ESERA SUMMER SCHOOL 2016

CONTENT

ESERA

ESERA (European Science Education Research Association) was formed in Leeds, England, in April 1995. The main aims of this association are to enhance range and quality of research and research training in science education in Europe, provide a forum for collaboration in science education research between European countries, represent the professional interests of science education researchers in Europe, seek to relate research to the policy and practice of science education in Europe and foster links between science education researchers in Europe and similar communities elsewhere in the world.

There are also special interest groups (SIGs) in the ESERA: SIG 1 (Early Years Science), SIG 2 (Video-Based Research of Teaching and Learning Processes), SIG 3 (Science Education in Out-of-School Contexts), SIG 4 (Science, Environment, Health) and SIG 5 (Science Identities).

EUROPEAN SCIENCE EDUCATION RESEARCH ASSOCIATION ESERA

ESERA SUMMER SCHOOLS

The summer schools for science education PhD students are held every two years. The students have possibility to present their research work at these summer schools and discuss its strenghts and weaknesses. Students work in the small groups of approximately 7 students and two experienced „coaches“.

The participants of the summer school also attend plenary lectures and workshops provided by experienced tutors as well as social events prepared by organizing committee. The maximum number of participants is 49 so students work in 7 groups. The number of staff members differ each summer school but normally it is about 18 persons. If more than this number applies, then participants are selected to ensure diversity of countries, gender and fields of interest.

Any PhD students who are members of ESERA are welcomed to apply for the summer school. Participant should not be too near to the beginning or end of their PhD study to be able to contribute of the attendance in their future work as well as discuss their preliminary findings. All staff members have to be members of ESERA. These experienced researchers and supervisors act as „coaches“ and some of them also provide pleanary lectures or workshops.

The first ESERA summer school was held in the Netherlands in 1993. The second summer school took place in 1994 in Greece. Since then, Summerschools have been held at two year intervals. The ESERA Executive Board decided to organize a trial summer school in June 2017 so the summer schools will take place every year again.

LIST OF PREVIOUS SUMMER SCHOOLS

- 2016: České Budějovice, Czech Republic
- 2014: Cappadocia, Turkey
- 2012: Bad Honnef, Germany
- 2010: Udine, Italy
- 2008: York, United Kingdom
- 2006: Braga, Portugal
- 2004: Mülheim, Germany
- 2002: Radovljica, Slovenia
- 2000: Gilleleje, Denmark
- 1998: Marly-le-Roi, France
- 1996: Barcelona, Spain
- 1994: Thessaloniki, Greece
- 1993: Zeist, Netherlands

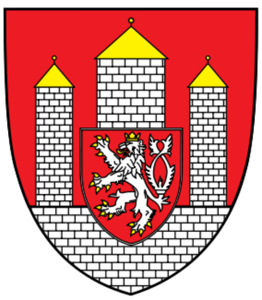
ESERA SUMMER SCHOOL 2016

THE VENUE – ČESKÉ BUDĚJOVICE

České Budějovice (*Budweis* in English or *Böhmisch Budweis* in German) is the largest city in the South Bohemian Region. It is political and commercial capitol of this area and also seat of the University of South Bohemia and Academy of Sciences. The city is located in the valley of the Vltava River at the confluence with the Malše River. The city has 93 285 inhabitants (2015).

BRIEF HISTORY

České Budějovice was founded by the King Ottokar II of Bohemia in 1265 as royal city so the king could strenghten his position of power in South Bohemia. The first inhabitants and settlers came from the Bohemian Forest and Upper Austria. The strong fortifications made the city strategically important place during the Hussite Wars. The sixteenth century brought the city unprecedented prosperity and considerable profits flowing into the city coffers particularly from the local silver mining as well as from the beer brewing, fish farming and the salt trade. As a part of the Habsburg Monarchy from 1526, Budejovice remained a loyal supporter of Emperor Ferdinand II in the Thirty Years' War. Budějovice underwent a short occupation by Prussia during the Silesian Wars and the war between the Habsburgs and the French army in 1742.



The horse-drawn tramway, erected between 1825 and 1832 as the first on the European Continent, linked České Budějovice to the upper Austrian city of Linz, and together with the Vltava Waterway accelerated the transportation of goods. New enterprises were established such as a pencil factory (Koh-i-Noor Hardtmuth in 1847), breweries, utensil factory etc. After 1990 it became a statutory city with its own city mayor. Traditional commercial and cultural relations were restored with Austria, Germany and other European countries.

During the Second World War in March 1945, Budějovice was twice targeted by US Air Force raids that greatly damaged the city and caused great loss of life. At the end of the war, on 9 May 1945, Soviet troops liberated the city. On the following day, the Red Army and the American Army met on the main square in a joint celebration of the city's liberation.

SIGHTS

The old town preserves interesting architecture from the Gothic, Renaissance, Baroque, and 19th century periods. This includes mainly buildings around the large Ottokar II Square. The most valuable historic building in České Budějovice is the Dominican convent with the Gothic Presentation of the Virgin Mary church from the 13th century, on Piaristic Square

Selected sights:

- Otakar II Square with Samson fountain
- Historical City Hall
- Black Tower and St. Nicholas Cathedral
- Piarist Square
- Panská street
- City fortifications

UNIVERSITY OF SOUTH BOHEMIA

The University of South Bohemia (USB) is a public university located in České Budějovice. The university has 11,000 students in more than 200 bachelor, masters and doctoral programmes at 8 faculties – Faculty of Economics, Faculty of Fisheries and Protection of Waters, Faculty of Philosophy, Faculty of Education, Faculty of Science, Faculty of Theology, Faculty of Health and Social Sciences, Faculty of Agriculture. The university also offers courses and education programmes for the general public.

HISTORY OF USB

The University of South Bohemia was founded in 1991, following the tradition of educating teachers and university experts in various fields of agricultural production, theological studies and the tradition of fish farming and fisheries.

The University originally consisted of two faculties - Faculty of Education (since 1948 a branch of the Faculty of Education of Charles University, which later became an independent faculty) and the Faculty of Economics (since 1960 part of the Prague

University of Agriculture). The three newly created faculties also became the University's foundation stones: Faculty of Biology, Faculty of Theology and Faculty of Health and Social Studies. In 2006, the Faculty of Philosophy, then one year later, the Faculty of Economics were also established. The original Faculty of Biology was replaced in 2007 by the Faculty of Science. In 2009, the Faculty of Fisheries & Protection of Waters was established.

The University of South Bohemia collaborates with more than 300 universities around the world. It supports foreign study and research trips by students and academic staff.

USB CAMPUS

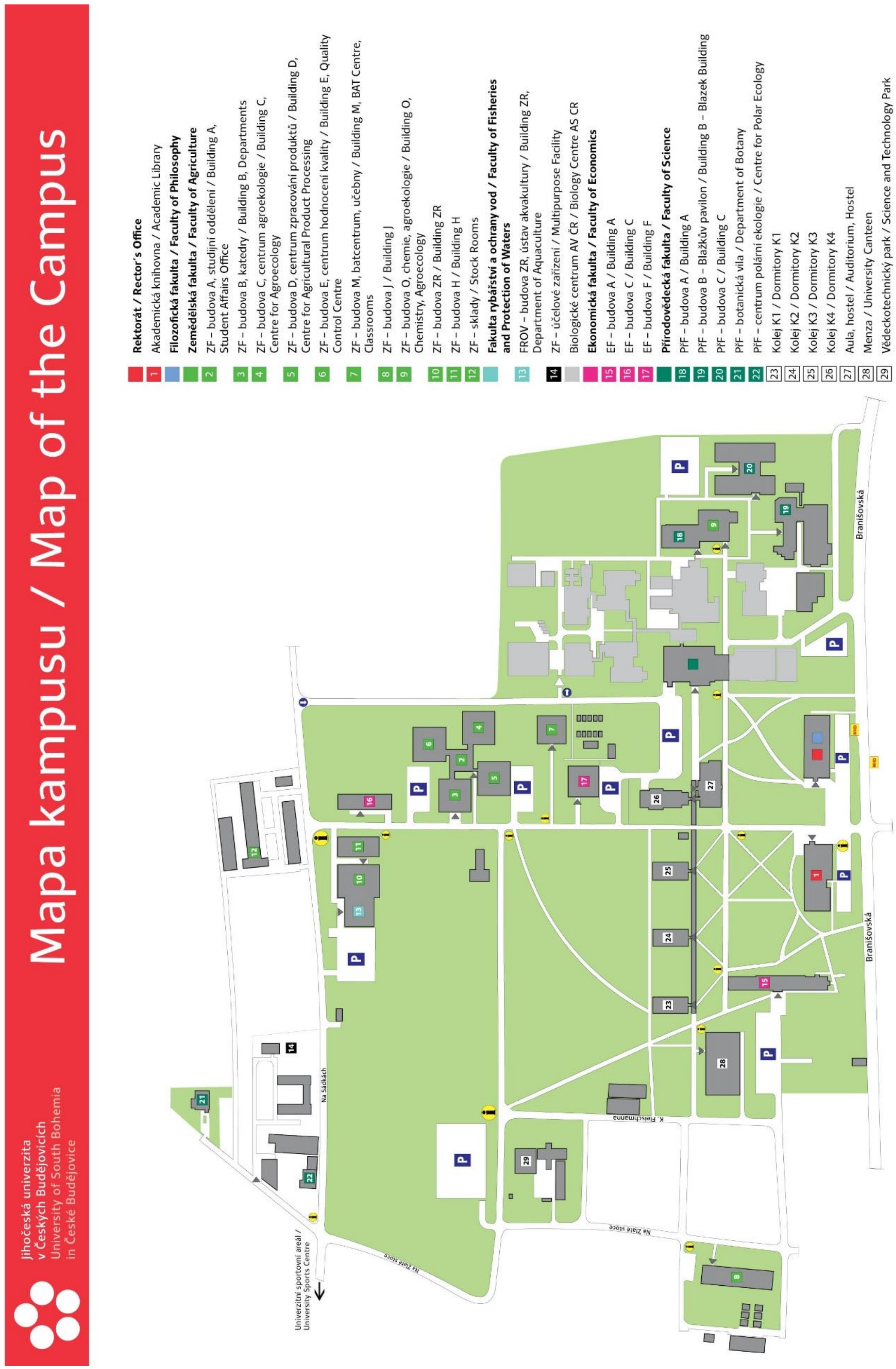
The campus is located in a quiet part of the town and it is used for relaxation, cultural and social events. An English style park has been created. You will find there much greenery, sport grounds and benches, including the unique Václav Havel benches designed by the architect Bořek Šípek. The nice roads and modern lighting create a positive atmosphere.

The campus regularly hosts concerts and events for students and the general public: The first year student welcome, Building a May poll, Light Show, Waste Show and many others.

You can also walk along the nature trail in the tree lined avenue, walk around the experimental plots and animal pens. The information boards contain interesting information on agriculture and the food industry.

The campus is under constant development. In 2014, the new contemporary science and technology building and a joint building for the Faculty of Agriculture and the Faculty of Fisheries & Protection of Waters are being finalized. Investment will continue over the forthcoming years with the development of a new university kindergarten and a student club.

VENUE – MAP OF CAMPUS



TRAVEL INFORMATION

The city of České Budějovice has convenient location close to the borders of three countries. It is approximately 100 km to Linz, 130 km to Passau, 150 km to Prague, 200 km to Vienna and 300 km to Munich. The easiest way is to fly to Prague International Airport (Vaclav Havel Airport Prague) and then travel by bus to Ceske Budejovice. Because the Prague airport is on the periphery, passengers have to use city transportation system. Student helping at ESERA Summer School 2016 will be at the airport and bus stations to help the participants of the summer school.

Private company called Regiojet provides comfortable yellow bus transfer with English speaking stewards, some snack and free internet on board. The buses go every hour and journey from Prague to Ceske Budejovice takes approximately 2 hours and 15 minutes. The first bus goes from Prague at 7:00 and the last one at 21:00. The organizing committee recommends using these buses and provides a booking of seats for this journey.

The schedule of Regiojet buses is also available at the following link:

- *https://jizdenky.studentagency.cz/Timetable?3&id=2740722009*

Prague – Ceske Budejovice		**Ceske Budejovice – Prague**	
Departure	**Arrival**	**Departure**	**Arrival**
7:00	9:20	5:40	7:55
8:00	10:20	6:40	8:55
9:00	11:20	7:40	9:55
10:00	12:20	8:40	10:55
11:00	13:20	9:40	11:55
12:00	14:20	10:40	12:55
13:00	15:20	11:40	13:55
14:00	16:20	12:40	14:55
15:00	17:20	13:40	15:55
16:00	18:20	14:40	16:55
17:00	19:20	15:40	17:55
18:00	20:20	16:40	18:55
19:00	21:20	17:40	19:55
20:00	22:20	18:40	20:55
21:00	23:20	19:40	21:55
		20:40	22:55

ORGANIZING COMMITTEE OF ESERA 2016

IVA STUCHLÍKOVÁ, leader of organizing team

I am a former teacher of mathematics and physics, but immediately after finishing my teacher training I went on in studying psychology. I got professorship in educational psychology in 2008, before that I worked also within general psychology research on emotions and motivation. My research interests are therefore divided between these two fields. An example of my recent research on motivation is participation in MARS 500, which was a broad international project of simulated flight to Mars. Within educational psychology domain my most favourite work recently was participation in two European 7FP projects on inquiry in science education (S-TEAM) and formative assessment (ASSIST-ME).

I joined the ESERA community just through this collaboration and I found the research and community life of ESERA very interesting and inspiring. Thus taking over to organize the Summer School 2016 is not only a challenge but a pleasure as well.

JAN PETR, member of organizing team

I am an assistant professor at the Department of Biology, Faculty of Education, University of South Bohemia. My scientific and research focus contains two fields. The first field is presented by enthomology, ecology and fauna of water insects, especially with focus on dragonflies (Odonata). The second field is theory of science education at pre-primary and primary level. I am also interested in didactical applicatin of methods of direct study of nature in the biology and integrated science lessons, e.g. school experiments or observations with the use of principles of inquiry based education.

LUKÁŠ ROKOS, member of organizing team

I am a full-time PhD student and lector at Department of Biology, Faculty of Education, University of South Bohemia. I have master degree in Biology and Chemistry Teaching for Secondary Schools. After finishing this study I immediately started my PhD study. I am interested in inquiry based approaches is biology education and assessment of these activities. Topic of my dissertation is *Assessment of inquiry-based scientific teaching in biology learning*.

I am member of research team in the international project ASSIST-ME (*Assess Inquiry in Science, Technology and Mathematics Education*) in which I am responsible for one local researching group in the Czech Republic focused on implementation of formative assessment into biology inquiry lessons at lower secondary level.

- Petra KECLÍKOVÁ
    - I am a student of Biology and English at Faculty of Education, University of South Bohemia. I have a bachelor degree in Biology and English Teaching for Elementary Schools and I currently continue with a master degree. I am writing my thesis on the Department of English and the theme is: Phraseologisms in English and Czech Online news. Because of my positive approach to life I am really looking forward to meeting new people through ESERA summer school and spending whole week learning new things.

- Lucie MIESBAUEROVÁ
    - I am a student of Biology and English at Faculty of Education, University of South Bohemia. I have a bachelor degree in Biology and English Teaching for Elementary Schools and I currently continue with a master degree. I am writing my thesis on the Department of Pedagogy and Psychology and the theme is: A perspective of students from Faculty of Education of University of South Bohemia in České Budějovice on alternative attitudes in education and on potential application of these methods in their practice. I was excited when I have heard about ESERA summer school, so I am looking forward to meeting new people in summer and learning new things about other countries.

- Jana VOMÁČKOVÁ
    - I am a student of Biology and English at Faculty of Education, University of South Bohemia. I have a bachelor degree in Biology and English Teaching for Elementary Schools and I currently continue with a master degree. I am writing my thesis on the Department of Biology and the theme is: The dialogue among students as a method of a peer assessment within inquiry tasks regarding human biology in biology lessons. I am very sociable person and I like meeting new people and learning new things.

SCHEDULE OF ESERA SUMMER SCHOOL 2016

	Sunday 21/08	Monday 22/08	Tuesday 23/08	Wednesday 24/8	Thursday 25/08	Friday 26/08
9:00	Arrivals	Opening	Group Work	Group Work	Group Work	Group Work Review
9:30		Lecture #1				
10:00						Lecture #5
10:30		Coffee / Poster	Coffee / Poster	Coffee / Poster	Coffee / Poster	
11:00		Group Work	Lecture #2	Lecture #3	Lecture #4	Coffee / Poster
11:30						Group Work Presentation
12:00			Lunch	Lunch	Lunch	
12:30						
13:00		Lunch	Poster session	Workshop	Informal time	Closing
13:30					Group Work	Lunch
14:00	Check in	Informal time	Informal time			
14:30		Group Work	Group Work			Informal time & Departures
15:00				Group Work	Coffee / Poster	
15:30					Workshop	
16:00		Coffee / Poster	Coffee / Poster			
16:30	Registration	Workshop	Workshop	Trip to Český Krumlov		
17:00						
17:30					Informal time	
18:00						
18:30		Informal time	Informal time			
19:00	Welcome Party	Dinner	Dinner		Dinner & Social program	
19:30						
20:00		Social program	Social program	Dinner		
20:30						

LIST OF REVIEWERS

- ACHIAM Marianne, University of Copenhagen, Denmark
- ALONZO Alicia, Michigan State University, USA
- BLAZEK Josef, University of South Bohemia, Czech Republic
- CEBESOY Ümran Betül, Usak University, Turkey
- CHAKRAVERTY Devasmita, IPN - Leibniz-Institute for Science and Mathematics Education, Germany
- CONSTANTINOU Costas, University of Cyprus, Cyprus
- DE HOSSON Cécile, University Paris Diderot, France
- DILLON Justin, University of Bristol, Great Britain
- ESPINET Mariona, University Autonoma de Barcelona, Spain
- HARMOINEN Sari, University of Oulu, Finland
- HENRIKSEN Ellen Karoline, University of Oslo, Norway
- HUANG Xiao, Zhejiang Normal University, China
- IDIN Şahin, Hacettepe University, Ankara, Turkey
- JIMÉNEZ-ALEIXANDRE María Pilar, University of Santiago de Compostela, Spain
- KARADEMIR Ersin, Eskişehir Osmangazi University, Turkey
- KAUERTZ Alexander, Leibniz University Hannover, Germany
- LAHERTO Antti, University of Helsinki, Finland
- NEHRING Andreas, Leibniz University Hannover, Germany
- PETR Jan, University of South Bohemia, Czech Republic
- ROLLNICK Marissa, Wits University, Republic of South Africa
- ROPOHL Mathias, IPN - Leibniz-Institute for Science and Mathematics Education, Germany
- RUSEK Martin, Charles University in Prague, Czech Republic
- STAVROU Dimitris, University of Crete, Greece
- STUCHLIKOVA Iva, University of South Bohemia, Czech Republic
- TELLI Sibel, Canakkale Onsekiz Mart University, Turkey
- TESTA Italo, "Federico II" University of Naples, Italy
- TOLSTRUP HOLMEGAARD Henriette, University of Copenhagen, Denmark
- VON AUFSCHNAITER Claudia, Justus Liebig University Giessen, Germany
- ZAVODSKA Radka, University of South Bohemia, Czech Republic

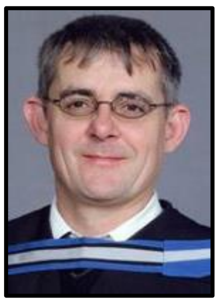
LIST OF PARTICIPANTS

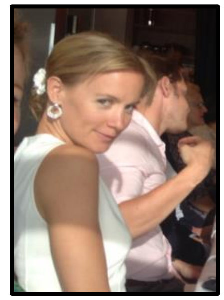
Total number of 51 PhD students (49 ESERA members and 2 students nominated by NARST) participate at the ESERA Summer School 2016. These participants were selected from 106 applicants. This summer school will be really “international event” because the participants of 22 different nations will meet in Ceske Budejovice.

ANDRADE Vanessa		BARTELS Hauke	
BINDER Torsten		BOHN Marcus	
BROCOS Pablo		COUPAUD Magali	
CULLINANE Alison		DANIPOG Dennis	

DAUS Stephan		DICKMANN Thomas	
DOKOPOLOU Maria		DUDZINSKA Matylda	
ELERT Thomas		FRÅGÅT Thomas	
FREJD Johanna		GALANO Silvia	
GÖK Emine		GÖRANSSON Andreas	

HABIG Sebastian 	HAYES Kathleen 
HOFER Elisabeth 	HOWARD Sally 
JOKIRANTA Kaisa 	KAMPHORST Floor 
KARLSSON Annika 	KAYA Sila 
KEHNE Franziska 	KIMPEL Lennart 

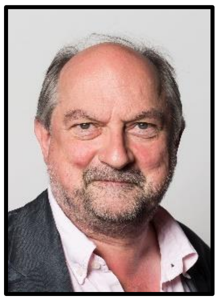
KLAPPAUF Ingmar			KOTKAS Tormi		
LEHTINEN Antti			LIVITZIIS Michalis		
MALCOLM Stephen			MCHUGH Martin		
METELKOVÁ Iva			MICHAILIDI Emily		
MÜLLER Joachim			NIELSEN Sanne Schnell		

PREGO Noa Ageitos			RYAN Laurie		
SHABY Neta			SJØBERG Mari		
SKORSETZ Nina			UBBEN Inga		
WADE Katherine			WALKOWIAK Malte		
WERNECKE Ulrike			WOITHE Julia		

YEOMANS Lucy  	YETER Ibrahim  
ZAPPIA Alessandro  	

LIST OF STAFF

21 persons from 14 different countries will serve as staff at the ESERA Summer School 2016. 17 of them will be coaches and they will work in small groups with PhD students. There will be 6 persons responsible for plenary plectures and 8 persons involved in workshops.

ACHIAM Marianne		ALONZO Alicia	
DILLON Justin		ESPINET Mariona	
EVANS Robert		FURTAK Erin Maria	
HARMOINEN Sari		HENRIKSEN Ellen Karoline	

HOLMEGAARD Henriette Tolstrup			CHEN Ying-Chih		
KAUERTZ Alexander			KORTLAND Koos		
LAHERTO Antti			ROLLNICK Marissa		
ROPOHL Mathias			RUSEK Martin		
RYBSKA Eliza			RYDER Jim		

TESTA Italo  	VON AUFSCHNAITER Claudia  
JIMÉNEZ- ALEIXANDRE Mariía Pilar  	

PLENARY SPEAKERS

- Alicia Alonzo (*Michigan State University, USA*)
- Claudia von Aufschnaiter (*Justus Liebig University Giessen, Germany*)
- Ying-Chih Chen (*Arizona State University, USA*)
- Erin Maria Furtak (*University of Colorado Boulder, USA*)
- Koos Kortland (*Utrecht University, Netherlands*)
- Antti Laherto (*University of Helsinki, Finland*)

WORKSHOPS LEADERS

- Justin Dillon (*University of Bristol, Great Britain*)
- Robert Evans (*University of Copenhagen, Denmark*)
- Sari Harmoinen (*University of Oulu, Finland*)
- Mariía Pilar Jiménez-Aleixandre (*University of Santiago de Compostela, Spain*)
- Alexander Kauertz (*University of Koblenz-Landau, Germany*)
- Mathias Ropohl (*IPN - Leibniz-Institute for Science and Mathematics Education, Germany*)
- Henriette Tolstrup Holmegaard (*University of Copenhagen, Denmark*)

SYNOPSIS

The synopsis were not corrected by the editors of this booklet. Authors of the papers are responsible for their quality, using appropriate references and grammar.

SESSION A: ASSESSMENT AND EVALUATION

EXPLAINING DIFFICULTIES IN LARGE-SCALE SCIENCE ASSESSMENTS

Stephan Daus

University of Oslo, Faculty of Educational Sciences, Norway

BACKGROUND

> "From a psychometrical perspective it is essential to have a good sample of items from the universe of possible items. On the other hand, from a science educator's perspective, the item-specific variance implies that each item is a universe in itself." (Olsen, Turmo, & Lie, 2001, p. 404)

The quote underlines the need for a deeper understanding of the science assessments. Per Morten Kind argues that all the large-scale assessment frameworks in science (the US National Assessment of Educational Progress, the Programme for International Student Assessment, and the Trends in International Mathematics and Science Study) have moved toward more advanced explanations of what constitutes the science construct (Kind, 2013a). He suggests that the explanation of this move may be a desire to support construct validity of the assessment by offering a rationale for the science domain. He further judges NAEP and PISA to have "the most elaborated explanations", with TIMSS being less developed (Kind, 2013a, p. 689).

Susan Embretson has earlier emphasised the possibility of deconstructing construct validity into nomothetic span, the web of relationships between the test construct and other variables, and the construct representation, the deeper theoretical structure underlying the item responses (1983). An eye to construct representation in science assessments thus not only implies classical validation studies but also a theory behind task performance. She furthermore stresses the need for operationalising alternative theories in quantitative models. This involves understanding the factors that influence the difficulty of an item or topic. The responses to the science assessments may be explained by the science assessment framework from where it originates, or by completely different and competing theories. This perspective has rarely been considered in large-scale assessments in general, according to Rutkowski et al. (2014).

THEORETICAL FRAMEWORK

One factor that influences item difficulty is opportunity to learn, and curriculum alignment in general. Opportunity to learn is usually divided into the intended curriculum (i.e. national standards and textbooks), enacted curriculum (i.e. classroom activities) and achieved curriculum (the student learning and test performance) (Porter, 1991). In Norway and many countries, the enacted curriculum is influenced by the teacher's decisions, which in turn are influenced by the teacher's cognitive and attitudinal competences. The teacher's self-efficacy in particular topics is thus expected to influence the quality of implementation of content, but also which contents are covered. However, teacher quality has rarely been studied together with differential curriculum alignment, and this necessitates a structural equation model approach.

Item difficulty can also be explained by reference to an alternative science assessment construct proposed as a substitute for the frameworks found in the large-scale assessment of interest (TIMSS). Despite modest intentions, it may perform comparatively well even if applied post-hoc to the assessment development. The science assessment framework proposed by Kind (2013b) is an attempt to resolve some of the issues Kind argues are present in the science frameworks of large-scale assessments. Kind focuses on scientific reasoning and his framework consists of two dimensions, that of 'fundamental science practices' (hypothesizing, experimenting and evaluation), and an orthogonal dimension of 'types of knowledge' (science content knowledge, procedural and epistemic). Whereas his framework is empirically supported, it has not been applied to existing large-scale assessments. The science learning characteristics indicate intrinsic demand and could potentially be derived from a science assessment framework (e.g. Kind, 2013b from earlier) or from Duit's findings (2009). Examples are preconceived conceptions, development of epistemological competencies, etc.

Finally, Cognitive Load Theory (Sweller, Ayres, & Kalyuga, 2011) represents a baseline theory for explaining differences in item difficulty, and thus an alternative hypothesis to the two previously mentioned frameworks. Cognitive Load Theory has its roots in cognitive psychology and evolutionary psychology. It aims to explain task demand by reference to information load and task complexity, and therefore ultimately predicts the difficulty of items in a science assessment not on the complexity of the scientific processes, or the abstractness of the science concept. Instead, it would refer to the arrangement and complexity of the information in the item stem, language clarity, the memory-recall aids of diagrams, and the number of simultaneous mental processes to be performed (Ibid.). Some of the ideas of Cognitive Load Theory, albeit implicitly, have already been applied on large-scale assessment data. Mullis et al. investigated the impact of number of words, vocabulary difficulty, symbolic language and visual displays on item difficulty for the 4th grade mathematics, science and literacy items in TIMSS and PIRLS 2011 (2013). Science education theories of why students struggle with content ought to better explain differential content performance than such a straightforward look to extraneous (irrelevant) item demand such as 'the number of words in the item stem'.

RESEARCH AIMS AND QUESTIONS

The PhD research project aims to explore the science assessment framework of TIMSS for deeper information than what is currently obtained.

In the first article, we explore how the cognitive science construct in TIMSS is operationalized, and whether more detailed topic-level performance information about the strength and weaknesses of the Norwegian student population can be extracted from the data, beyond what is usually reported in the official reports.

In the second article, we use psychometrical simulations (based on real data) with varying country sample size, heterogeneity of variance and framework item blueprint, to evaluate the generalizability, robustness and practicality of the method explored in the first article. These two articles establish the feasibility of the method used in the subsequent articles.

In the third article, we pose three hypotheses about the relationships regarding differential curriculum implementation. First, because students are engaged in "unique" material in which the teacher is engaged or confident, students will find that taught content that should not have been taught is easier than “aligned content” – content that should be taught and is taught. Second, because some content (e.g. mathematics-demanding content with counter-intuitive concepts) is more susceptible to opportunities to learn (e.g. schooling) than other content, the relationship between curriculum alignment and achievement varies across content. Third, self-efficacy in teaching content is directly and positively related with achievement (a quality factor); whereas self-efficacy in teaching content is indirectly related with achievement through the mediation effect of content misalignment (a quantity factor).

In the fourth article, we evaluate whether performance difficulties are better predicted by conceptual learning problems, as derived from the science education literature, than the baseline – exogenous demands as derived from Cognitive Load Theory literature.

METHOD

The data used to answer all the research questions are the science responses of the TIMSS 2011 survey, in particular the 3600 Norwegian students. The third and fourth articles require mapping of the 245 items to curriculum documents, science education learning theory indicators and Cognitive Load Theory indicators.

A core method of the research project is the use of explanatory item response models (de Boeck & Wilson, 2004). Descriptive item response models like the Rasch model (Rasch, 1960/1980) model item responses on persons and items so that person ability is mapped on the same scale as item difficulty. The explanatory item response models allow the ability, item difficulty and interactions between the two to be further modelled by student characteristics, item characteristics or characteristics of their interactions. An example of the latter is the modelling of the implemented curriculum which in TIMSS is given for each class by each science topic. Essentially all the research questions in the project use explanatory item response models.

PRELIMINARY FINDINGS

The research project is completing the first article (and has begun the third article). The findings from the first article show that, as compared with the person-side where most science research tends to focus, there is a relatively large amount of variation in responses to the science items that can be explained by the item-side. The content groups (science domains and within-domain topics) vary considerably in difficulty, and the variation in item difficulty varies between domains and between topics. There are also indications that the varying degree of curriculum implementation has an effect of topic difficulty. Preliminary results from article three are also encouraging.

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Kind, P. M. (2013a). Conceptualizing the Science Curriculum: 40 Years of Developing Assessment Frameworks in Three Large-Scale Assessments. *Science Education, 97*(5), 671-694. doi:10.1002/Sce.21070

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CHALLENGES AND PROSPECTS IN TEACHERS' USE OF FORMATIVE ASSESSMENT FOR LOWER SECONDARY SCHOOL STUDENTS' MODELING COMPETENCE IN BIOLOGY

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FOCUS OF MY STUDY

This design-based research project is aimed at facilitating Biology teachers' use of formative assessment of students' modeling competence in lower secondary school. Teacher's use of formative assessments holds prospects to enhance students' learning, but it requires professional support, time and useful classroom materials (Bennett, 2011).

Models and modeling are central for teaching and learning science and are seen as a core practice in science and scientific literacy (Gilbert & Boulter, 2000; Lehrer & Schauble, 2015). Modeling holds prospect for facilitating students learning of science concepts, scientific reasoning processes and awareness of how science operates (Nicolaou & Constantinou, 2014). Although modeling has taken a prominent position internationally in science education, it is challenging for teachers to understand, use and assess students learning related to modeling (Schwarz et al., 2009; Khan, 2011).

The modeling competence plays a central role in the recently revised science curriculum in Denmark. Teachers are expected to assess students learning progress targeting the modeling competence in their daily teaching. Accordingly, the teachers must understand this goal and have suitable assessment criteria and methods at hand. But anecdotal evidence suggests that Danish biology teachers have limited experience in assessing students learning achievements regarding scientific modeling.

In the official curriculum documents, the description of the modeling competence and the achievement goals that couple modeling practice with content knowledge are formulated only in general terms and not based on a systematic theoretical framework (Nielsen, 2015). This can be problematic because teachers' interpretation of the concepts then becomes of central importance for how the modeling competence concept is put into practice.

Moreover, minimal curriculum resources are provided (a) to demonstrate relevant criteria for assessing whether, or at which level, the modeling competence is being achieved and (b) to suggest relevant methods for assessing students' learning in the practice of scientific modeling. Therefore, before the modeling competence concept can be transformed into assessment practice in the classroom, teachers must (a) interpret and unfold the modeling competence concept and develop assessment criteria based on her/his own perception of relevance and of the expected level of performance suited to each specific content and grade, and (b) consider a relevant assessment method.

Given Danish school teachers' (i) novelty of modeling competence, (ii) limited experience in using formative assessment targeting this competence, and (iii) lack of curriculum materials to identify what kinds of performance are indicative of this complex competence, there is a need to better understand how to form and use adequate assessment methods. This need underlines the research questions for this project.

RESEARCH QUESTIONS

What kind of challenges and prospects may arise when Biology teachers use a dialogical assessment method and criterion-referenced rubrics for formative assessment of students' modeling competence?

Sub-questions

A) What characterizes Danish teachers' current belief, use and formative assessment with respect to models and modeling in Biology?

B) What kind of criteria are suitable for designing criterion-referenced rubrics to support biology teachers' formative assessment of students' modeling competence?

C) What kind of challenges and prospects arise when teachers use predesigned rubrics (i) to facilitate their understanding of the modeling competence, (ii) to design content specific rubrics, and (iii) to use the rubrics for formative assessment of students modeling competence through a dialogical assessment method?

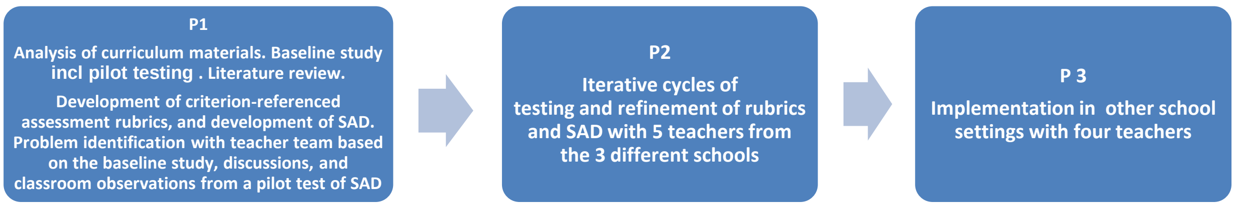
SHORT REVIEW OF RELEVANT LITERATURE

The project has been shaped mainly by research literature on the primary value of formative assessment for facilitating students' learning (e.g. Black & Wiliam,2009; Bennett, 2011). The focus on models is informed especially by the approach of Gilbert and Boulter (2000), where models are seen as systems of objects, symbols, and relationships representing a real system being studied. The target studied could be an idea, object, event, process, or system, and the model could be mental or expressed. I have chosen to focus on modeling as a core scientific practice with prospect for incorporating other science practices (Lehrer & Schauble, 2015). In this study, modeling competence also includes meta-knowledge e.g. students knowledge and reflections on the nature, use and purpose of models, and the criteria for evaluating them (Schwarz et al., 2009), including students' reflections on how models and modeling can facilitate their own learning (Nielsen, 2015). A differentiated assessment of students understanding of the different aspects of models and modeling must take into account that students seem to have a complex and at least partly inconsistent pattern of understanding (Krell et al., 2014).

It is challenging to identify indications of competence performance (Grob et al., 2014). The use of rubrics in this study is inspired by Smith and Birri (2014) who suggested that teachers' design and use of rubrics can foster understanding of complex competences in science. In addition, rubrics have potential to improve instruction because they make expectations and criteria explicit, which facilitates feedback and self-assessment (Panadero & Jonsson, 2013). The assessment method developed in this project will take into account that dialogue-related factors are important for students learning and hold prospect for formative assessment (Ruiz-Primo, 2011).

OUTLINE OF THE RESEARCH DESIGN AND METHODS

The project is divided into three Phases (P). P1 is a nationwide questionnaire baseline study aimed at characterizing teachers' current belief, use and formative assessment with respect to models and modeling in Biology. In addition P1 is aimed at identifying key challenges for teachers to use the intended curriculum, and for designing a special assessment method, the structured assessment dialogue (SAD), and corresponding rubrics. P2 is aimed at examining what kind of challenges and prospects that arise when teachers use the SAD and rubrics from P1. P3 will examine the generalizability across different contexts.



The development of the SAD will be based on previous work (Grob et al., 2014; Christensen, 2004). The SAD will integrate learning and assessment modeling activities and take into account six criteria that may impact how assessments affect students' learning: (i) Consistency between goals, teaching and assessment approaches (Bennett, 2011), (ii) Consistency between goals and observable assessment criteria adapted to specific teaching sequences (Krajcik et al., 2008), (iii) Use of rubrics to make expectations and criteria explicit (Panadero & Jonsson, 2013), (iv) Student awareness of the criteria (Black & Wiliam, 2009), (v) Student involvement, incl. 'self-assessment' (ibid.), and (vi) Built-in dialogues, among the students - and with the teacher (Ruiz-Primo, 2011). Data materials for P2 & P3 will be: teachers' instruction plans and rubrics, video records of teacher and pupil interactions during SAD, teachers' written feedback to students, interviews with students after they have received feedback, and observations and video records of the teachers' responses to their own formative assessment practices. The responses will be generated by the model "Sophos", where teachers in teams observe and comment on the documentation of their own practice (Hansen, 2005). These data will be analyzed to identify prospects and challenges in teachers' use of formative assessment in the context of this project.

PRELIMINARY FINDINGS/STATUS

The Summer school will be an opportunity to obtain feedback on: (i) the design of the rubrics and the SAD, (ii) the analytical work and results from the pilot test of SAD and the baseline study, (iii) refinement of P2 incl. its methods and analytical work, (iv) the relevance and framing of P3, and (V) refinement of the research questions.

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SESSION B: BIOLOGY EDUCATION

LOOKING AT MODELS OF AND FOR EVOLUTION: VISUAL PERCEPTION PROCESSES AND REPRESENTATIONAL COMPETENCE WITH PHYLOGENETIC TREES

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INTRODUCTION

Arisen from early tree depictions by Darwin and Haeckel, phylogenetic trees model evolutionary relationships among organisms. They are used by scientists for different purposes: as a medium to visualize known relationships and as a method to test and build new hypotheses. In contrast to science, the medial use of these models in school biology education is dominant (e.g. Ubben, Nitz, Rousseau, & Upmeier zu Belzen, 2015).

Reading phylogenetic trees comprises interpretation of the content and comparison of different representations. Even though correct tree reading is crucial for the understanding of evolution, one core concept of biology, most students struggle with phylogenetic trees (e.g. Baum, DeWitt Smith, & Donovan, 2005) showing low levels of representational competence (Halverson & Friedrichsen, 2013). Studies on phylogenetic trees are usually conducted using written answers and questionnaires about tree reading (e.g. Halverson, 2011) but the actual visual processes during tree reading were only subject to one study so far (Novick, Stull, & Catley, 2012). Hence, the present study deals with the question how participants visually perceive those highly visual representations and how the visual perception corresponds with the verbal reasoning during tree reading. The model character of phylogenetic trees and their different use as a medium or a method leads us furthermore to the question whether the use of the model has an influence on visual perception and the verbal reasoning, respectively.

THEORETICAL BACKGROUND

In general phylogenetic trees depict hypothesized evolutionary relationships among a group of organisms, the so called taxa (see Figure 1). Depending on the data they base on and their purpose, different kinds of phylogenetic trees can be built following special conventions.[1]

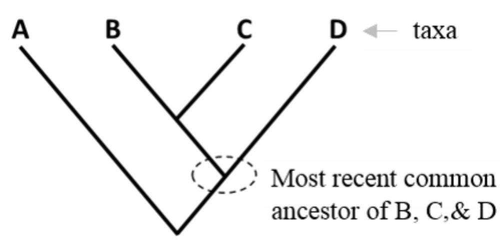

Figure 1: This phylogenetic tree depicts the evolutionary relationships of four taxa by indicating the most common recent ancestors as nodes.

[1] Since nomenclature is not used consistently within the scientific community, this synopsis will use the term phylogenetic tree as a general term for all models and representations of evolutionary relationships.

The general model character of phylogenetic trees - independent from their data base and content - occurs in two different scenarios: as a model *of* evolutionary relationships phylogenetic trees are used to represent known hypotheses about those relationships; as a model *for* evolutionary relationships they serve to test hypotheses and to gain new insights and hypotheses (according to Mahr, 2008, 2009; Passmore, Gouveau, & Giere, 2014). As a model *of* evolutionary relationships phylogenetic trees are used as a medium to represent information. In contrast phylogenetic trees as a model *for* evolutionary relationships are handled as a method (Gilbert, 1991; Mahr, 2009). The framework of model competence (Grünkorn, Upmeier zu Belzen, & Krüger, 2013; Upmeier zu Belzen & Krüger, 2010) predicts that handling of phylogenetic trees can take place on three different levels: description (level I) and explanation of the content (level II) as medial aspects on the one hand and the more elaborated use for prediction and inquiry purposes (level III) as methodical aspects on the other hand.

As a study of phylogenetic tree representations in selected German textbooks revealed (Ubben et al., 2015) the methodical use of phylogenetic trees is underrepresented in school biology education. In contrast to the use in science the model competence with phylogenetic trees on level III might thus not be promoted at school.

The ability to use, think about, and to reflect the underlying processes and characteristics of phylogenetic trees, namely representational competence (Kozma & Russel, 2005), can be ranked into seven different levels (Halverson & Friedrichsen, 2013). Students' representational competence with phylogenetic trees is here often limited to low levels like no use of the representation or only use of superficial features of phylogenetic trees. Hence, a more elaborated use of the underlying meaning in a scientific manner is rare and only to accomplish via extensive training (Halverson & Friedrichsen, 2013).

Regardless of the level of representational competence, handling phylogenetic trees is a highly visual process. Nevertheless, only one study investigated visual perception of phylogenetic trees so far (Novick et al., 2012) with the finding that the orientation of the phylogenetic tree has an impact on correct tree reading. According to the work of Just and Carpenter on eye tracking (1976), an observer's attention lies on the location or object he or she fixates with the eyes. Hence, we assume that eye tracking of phylogenetic trees allows for conclusions about which areas and features are of the observer's interest when reading those trees and that this will be reflected in verbal reasoning. Furthermore, we suggest that the visual perception during tree reading changes according to whether a phylogenetic tree is presented in a medial or methodical scenario. Regarding the different levels of representational competence with phylogenetic trees we also suggest that the medial and methodical scenario require different levels of representational competence.

As participants we chose pre-service biology teachers who are in the last part of being educated in evolution and tree reading before they pass on their knowledge to students at school.

RESEARCH QUESTIONS (RQ)

1) To which extent is the pre-service biology teachers' visual perception consistent with their verbal reasoning while interpreting and comparing phylogenetic trees?
2) How does pre-service biology teachers' visual perception of phylogenetic trees differ depending on the medial or methodical use of phylogenetic trees as a model?

3) How do pre-service biology teachers' levels of representational competence with phylogenetic trees in verbal reasoning differ depending on the medial or methodical use of phylogenetic trees as a model?

RESEARCH DESIGN AND METHODS

Participants are 30 pre-service biology teachers from Berlin. We use a remote eye tracker system (SMI) to record participants' eye movement data, namely fixations and scan paths on presented phylogenetic trees. For this purpose, multiple-choice tasks about tree interpretation and tree comparison (the two aspects of tree reading) are presented on the stimulus screen and participants are instructed to answer them by clicking the correct response option. After every task participants explain and justify their choice by retrospective think aloud (verbal reasoning). Eye tracking data is analyzed by measuring number, order, and frequency of fixations and scan paths in predefined areas of interest (inter alia nodes, taxa, lines). Verbal explanations and justifications are coded according to which representational features of the phylogenetic trees are indicated by the participants (inter alia nodes, taxa, lines). Subsequently eye tracking data and coded verbal data are compared with regard to where participants looked at and verbally indicated to look at when handling phylogenetic tree representations in order to determine consistency.

For RQ 2 we gain data on visual perception as for RQ 1 but with tasks in a 2x2 design: Tasks on either tree interpretation or tree comparison (AV) are given either for phylogenetic trees in a medial or in a methodical model scenario (UV).

To answer RQ 3 the same tasks as for RQ 2 are used. Participants' justifications and explanations are coded according to the seven levels of representational competence by Halverson and Friedrichsen (2013).

IMPLICATIONS

Our study will give deeper insight into visual perception of phylogenetic trees and its connection to verbal reasoning. Phylogenetic trees as models *of* and *for* evolutionary relationships are important to understand the concept of evolution but still we do know little about how they are processed. Hence, our understanding of visual perception and verbal reasoning processes of phylogenetic trees in different scenarios (medial vs. methodical use of models) will help to improve teaching phylogenetic trees in school and university.

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INTERACTIONS BETWEEN ARGUMENTATION AND MODELLING IN GENETICS' INSTRUCTION ABOUT HUMAN DISEASES

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RATIONALE AND RELEVANCE OF THE STUDY

Viewing science learning as participation in the practices of science is a framework gaining force in both science education research literature and recent policy documents (NRC, 2012). According to Berland & Reiser (2009), learning science involves the participation in the scientific practices. The term scientific practices refer to “the specific ways members of a community propose justify, evaluate, and legitimize knowledge claims within a disciplinary framework” (Kelly, 2008, p.99). Argumentation and modelling are both identified as core scientific practices in the K-12 Framework (Achieve, 2013) and are appearing in EU curricula. The science education literature highlights the importance of investigating the relationships between modelling and argumentation in specific contexts (e.g., Mendoça & Justi, 2014; Passmore & Svodoba, 2011), and their consequences for the development of skills related to critical thinking.

Our view of argumentation is in line with Jiménez & Erduran (2007), who consider this practice as the evaluation of knowledge based on evidence and as a social process in which students involve in the interchange of ideas and their evaluation (Evagorou & Osborne, 2013). According to Schwarz et al. (2009), modelling includes the elements of the practice (constructing, using, evaluating, and revising scientific models) and also the meta-knowledge that guides and motivates the practice (e.g., understanding the nature and purpose of models). This research attempts to show the interplay between both practices, modelling and argumentation, in the context of learning genetics by secondary students.

The unit designed requires modelling gene expression for understanding molecular processes that are involved in the manifestation of genetic diseases. Students engage in the construction of causal explanations of different diseases based on the application of the model of gene expression.

SHORT REVIEW OF LITERATURE

The research draws on literature on scientific practices and students' learning about genetics. The main reasons for addressing this research area are in line with Todd and Kenyon (2015): a) it is a core content in biology curricula; b) it is a field that rapidly advances due to the availability of new technologies; c) it raises difficulties for teaching and learning; d) it has social implications.

Previous studies about the model of gene expression reveal deterministic views in students discourse in different contexts of application the model of gene expression (Puig & Jiménez, 2012). Research on molecular genetics points to teachers' and students' difficulties for teaching and learning genetics respectively (Todd and Kenyon, 2015). One of the difficulties pointed by Jiménez-Aleixandre (2014) is that students more easily adopt models of cause-effect relationships than models in which multiple factors affect the phenotype. Taking into account these difficulties and Dawson & Venville (2010) recommendations for using modelling to help the students to understand processes that are not visible, this research uses a modelling-based approach for the comprehension of genetic diseases and as a way to overcome deterministic positions. A study by Duncan *et al*. (2009) suggest that the risk of students to develop a determinist view is greater when they lack explanatory mechanisms that link genes to traits, being unaware of what organization level the genetic information specifies. Modelling gene expression may help the students to understand molecular processes involved in the manifestation of genetic diseases.

Kampourakis et al. (2014) argue that the content of genetics taught in schools does not accurately represent the knowledge in the field, especially the knowledge that is relevant to understand SSIs. These authors point to two distinct components in genetics literacy; one is related to the traditionally taught in classrooms (basic genetic notions), and the other to questions that students may encounter as citizens. This study pays attention to the second component, genetics learning for citizenship. The focus of our study and the embedded teaching unit is on the application of the model of gene expression in the context of explanation and decision-making on different genetic diseases.

RESEARCH QUESTIONS

The study seeks to make a contribution to science education research on modelling and argumentation, putting the emphasis on the examination of the interplay between both practices in the context of explaining different genetic diseases. The research questions that guide the research are:

1) *How are the interactions between modelling and argumentation when building the model gene expression?*
2) *How are students' discursive narratives in the context of explanation of a human disease?*

RESEARCH DESIGN AND METHODS

The research seeks to examine the interplay of modelling and argumentation in a secondary school students' classroom (15-17 years old) during two years (2014-2016) of implementation of a genetics unit. The participants are twenty students and their biology teachers (T1 and T2). The first year the two teachers were involved and the second year only T1 is participating. Teachers experience in modelling-based activities differs. T1 has been involved in a previous study on modelling-based learning in geology and he also uses his own modelling activities in his current biology and geology lessons. T2 has not previous experience in modelling-based activities.

Design and description of the units: the process of design is iterative; the first year of the thesis (2014-2015) a first unit (unit 1) on genetic diseases was discussed and developed with the two teachers (T1, T2) and an international expert in clinical genetics. The unit consists of four activities developed in six sessions by all the students in small groups, and also a pre-test and a post-test performed individually.

Attending to some students' difficulties to engage in modelling and argumentation practices and teachers' need of a better understanding on how to introduce these practices in a significant manner, two workshops (6 hours) have been carried out. These workshops engage T1 in different activities of modelling and argumentation as a way to help him to understand these practices and its role to promote them. In addition to the workshops, four meetings with T1 have been also carried out in order to discuss about the design of a second unit (unit 2). Unit 2 comprehends activities on argumentation and modelling genetic diseases and evolution. Table 1 summarizes the activities implemented in the two units.

Session	Task	Students' enactment
School year 2014/2015 (Unit 1)		
	Pre-test: What do we know about models, and genetic diseases?	Evaluate models, define scientific models and explain genetic diseases
1,2	*Modeling sickle cell disease*	Modelling the gene expression of sickle cell disease with a kit.
3, 4	*First aid workshop and explaining sudden death*	Carry out cardiopulmonary resuscitation (CPR) techniques. Looking for information and using criteria to explain sudden death.
5	*Jolie´s effect*	Making evidence-based and argued decisions about diagnosis and treatment of breast cancer.
6	*Linking sickle cell disease and evolution*	Making sense of data to explain the evolutionary links between two human diseases.
	Post-test: Transfer the model of gene expression to a new context	Revising the model by explaining the relationship between malaria and sickle cell anemia..
School year 2015/2016 (Unit 2)		
1	*Models in science*	Defining model in science and using criteria to choose the best model
2,3	*Why do pigs die?*	Making and contrasting hypothesis, using evidence and applying the model of gene expression
4-6	*Modelling evolution*	Simulating natural selection and modelling evolution
	Post-test	In process

Table 1: Summarized activities (Unit 1 and 2)

The methodological approach is qualitative and draws from discourse analysis (Gee, 2005). It corresponds to a case study, which involves describing complex phenomena and human interactions in great depth (Yin, 2003; Lapan, 2012).

During the implementation of unit 1 the data collected include: a) the pre-test exploring students understanding of the meaning of models and genetic diseases, b) audio and video recordings of all sessions, c) student' models of gene expression to explain sickle cell disease (activity 1), d) written reports of all the activities, e) the post-test, f) field notes with observations of relevant events during the sequence.

The analysis of question 1 focuses on the identification of the interactions between modelling and argumentation, and on which type of operations are involved in these interactions. For addressing question 1, we examine oral transcriptions from activity 1, *Modelling sicke cell disease*, focusing on one group, group 1. Drawing from previous research on the operations in argumentation (Jiménez-Aleixandre et al., 2014), we identify a set of argumentative and modelling operations in students' talk while modelling gene expression.

For the analysis of question 2, the focus is on the small groups' written reports and on the oral transcriptions of activity 6, *Linking sickle cell disease and evolution,* which is in process. We draw from content analysis (Bardin, 1996) for addressing this question. The focus is on the background knowledge and the data used by the students in their discursive narratives.

PRELIMINARY FINDINGS

According to the first task about modelling gene expression, preliminary findings show that when the students explain and share their models, they enrich the explanation of the processes and link the elements that in the model seem to be unrelated. These findings point to the importance of using a modelling-based approach as a way to help students to understand molecular processes that are involved in gene expression. Further analysis will be paying attention to the interactions between modelling and argumentation in terms of finding out whether these practices promote each other and in which way do they contribute each other.

The analysis of the question 2 allows us to identify four types of discursive narratives according to their background knowledge: *historic*, *genetic*, *cultural*, *and evolutionary*. Some groups build their explanations on historic ideas about black slaves and attribute only to blacks the origin of sickle cell disease. This result has social implications related to biological determinism.

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PUPILS' CONCEPTIONS OF BIOLOGICAL EVOLUTION THROUGHOUT SECONDARY SCHOOL IN FRANCE

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INTRODUCTION

The biological theory of evolution (ToE) is fundamental knowledge for understanding modern biology. Teaching the evolution of living species is today at the heart of many studies from primary school to university (Coquidé & Tirard, 2009). It is complex and involves another way of thinking science. Since Darwin, the theory of evolution evolved towards a synthetic stage (David & Samadi, 2011), which at present, leans essentially on the fact that genetic mutations are random. The notion of randomness appears then as being a key element of this new theory (Merlin, 2011), and in particular, the contribution of contingency in natural selection. Moreover, when we are concerned with teaching the evolution of living species, strong beliefs held by students may impede their learning of the evolution of life (Basel et al., 2014; Foster, 2012; Reiss, 2014). In our research, we analyze the place of the ToE in the French curriculum with a specific focus on secondary school students' explanation of biological evolution related to the contribution of randomness in the process of evolution.

REVIEW OF LITERATURE

Students' ideas about evolution

The difficulty for students to accept evolutionary ideas has been shown to be either directly linked to the intrinsic conceptual difficulty of the theory of evolution, or linked to non-scientific ideas (Aroua, Coquidé & Abbès, 2013). The first type of difficulties concerns the dynamic of the evolutionary model and the related mechanisms, in particular, natural selection (van Dijk & Reydon, 2010; Smith, 2010). The second type is linked to cultural or sociocultural factors (Hanley, Bennett & Ratcliffe, 2014; Yasri & Mancy, 2014).

There are few studies concerning primary school children and their idea about evolution (Campos & Sà-Pinto, 2013). Jégou-Mairone (2011) underlines the fact that, despite the difficult nature of the topic, the majority of primary school children tested in France accept the idea of evolution. However, they have a conception qualified as "fixist" with a divine origin of life followed by evolution. This idea becomes predominant in schools where religious education at home is also very present. Very often they mention God to justify their choice, although creationist ideas are rarely found. Concerning secondary school in France, Fortin (2010) reveals four types of conceptions: from an evolutionary conception (close to the actual theory) to a creationist conception (discharge to the actual theory).

EVOLUTION IN FRENCH CURRICULUM

It is important to remind that the French context is characterized by a strong dominance of secular values involving the absence of religion in public education. This leads to an orientation of teaching evolution related to its relationship to knowledge and trying to address the misconceptions that might be associated to that knowledge. In primary school, children approach the idea of species by discovering the diversity of living things and to identify objective criteria to sort them (MEN, 2008). The idea of evolution appears in secondary school in K6 with the use of the phylogenetic classification to highlight the evolutionary history and the relationship between organisms (MEN, 2008). The teaching of evolution really becomes explicit in K9 at the end of lower secondary school (also the end of common compulsory education in France) with a focus on the understanding of the link between the classification and evolution. The random changes of the mechanisms of evolution only appears toward the end of lower secondary school.

RESEARCH QUESTIONS

In this context, we retain that there are few studies in France about the teaching of ToE. Also, the ToE is an object complex to teach. Finally, we see that randomness, and more particularly contingency, is very important for the understanding of the ToE. So, we address the following research question:

- What are students' changes of conceptions regarding the theory of evolution throughout secondary school in France?
- What is the correlation between students' conceptions on the evolution of species and their idea of randomness (random, contingency …)?

METHOD

To answer these research questions, we started several data collection: a first questionnaire to test students' knowledge and philosophical class discussions about the ideas of randomness. The analysis of this data will feed the construction of the new questionnaire to test the correlation between students' conceptions on the evolution of species and their idea of randomness.

First, to identify conceptions of primary and high school students and to study their evolution, this study used a written questionnaire (Coupaud et al., 2015). The questions test effective knowledge related to: (1) extinct animals, (2) existing animals or humans, (3) understanding of evolution mechanisms. The questionnaire submitted to approximately 245 secondary school pupils (K6 to K9) enables us to characterize their conceptions about the evolution of the living species.

Then, we identify students' ideas about randomness with philosophical class discussions. In two groups of students (25 students aged 10 and 25 students aged 13), debates were led by a researcher specialized in philosophical discussions. Students' discussions, lasting one hour in each group, were videotaped.

PRELIMINARY FINDINGS

The results of the first questionnaire show that the lower secondary school students tested in France mainly accept biological evolution and have knowledge about biological evolution. However, they mainly have a "transformist" conception, considering that living species undergo a metamorphosis and ignoring a random process through natural selection. It can be associated to Lamarck's ideas. The "transformist" conception is dominant in K9 students (at the end of compulsory education in France) to explain the mechanism of evolution.

The results of the philosophical class discussions about randomness show that students often associate randomness to chance but rarely to contingency. Generally, they have several ideas of randomness. This study reveals 6 different ideas that we categorized under: fate, luck, none existence of randomness, a consequence of human ignorance, probability, contingency.

Finally, these preliminary results about students' conceptions of evolution and the students' ideas of randomness will feed a quantitative work: the construction of a new questionnaire. This closed questionnaire consists of questions concerning randomness, and questions concerning the mechanisms of species' evolution. The objective is to measure the correlation between the students' conceptions about evolution and their ideas of randomness.

DISCUSSION

This preliminary study aims to identify students' conceptions of secondary education (K6 to K9) in order to consider the impact of school curricula during compulsory education. This study confirms this position by revealing conceptions accepting the idea of evolution. However, the majority of students tested have "transformist" conceptions, which means that they accept the idea of evolution, but see it as a metamorphoses of species under a stress due to the environment. This "transformist" conception constitutes a real obstacle to learn the theory of evolution. In parallel, we identified that students in philosophical discussions rarely express the idea of contingency. Our first interpretation of these results is that students stay in a "transformist" position because they might not take into account the contribution of randomness and in particular the contingency to explain the mechanisms of evolution of species. This conception totally excludes the idea of randomness and can be a major obstacle to the acquisition of real evolutionary thought. This research opens the way to explore the effect of introducing the idea of randomness earlier in school.

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WHAT TYPE OF PRIOR KNOWLEDGE MAKES STUDENTS SUCCESSFUL? – PRIOR KNOWLEDGE AS A PREDICTOR FOR ACADEMIC SUCCESS IN BIOLOGY AND PHYSICS

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RESEARCH GOALS

The purpose of our project is to analyse the influence of different types of prior knowledge on students' academic success in biology and physics. Based on the model by Hailikari (2009), we differentiate between four types of knowledge: knowledge of facts, knowledge of meaning, integration of knowledge, and application of knowledge. We assume that these types of knowledge predict academic success differently for the domains physics and biology. For instance, for the introductory biology courses (e.g. taxonomy in zoology), knowledge of facts and of meaning as well as the integration of knowledge seem to be more important than the application of knowledge. For the introductory physics courses, however, we hypothesize that the application of knowledge (e.g. using conservation laws in mechanics) is at least as important as the other three types of knowledge.

BACKGROUND AND RESEARCH QUESTION

The increasingly high drop-out rates for science study programs at German universities (e.g., 30% for biology courses; 40% for physics courses; Heublein et al., 2014) have led to heated discussions about how to support students, especially in their freshman year.

Academic success is influenced by a variety of general and subject-specific factors. So far, most studies in this field have focused on general, non-specific factors like grade point average (GPA; Dochy, Segers & Bühl, 1999). With regard to the improvement of study conditions, however, subject-specific factors are of particular interest. Especially students' subject-specific prior knowledge is a good predictor of their academic success (Hailikari et al., 2007, 2009, 2010). This is emphasized by the high predictive validity of subject-specific admission tests, too. For example the SAT, a subject-specific standardized university admission test, is showing incremental validity in addition to single unspecific predictors such as GPA (Gold & Souvignier, 2005). Whereas the majority of studies so far use rather unidimensional prior knowledge measures, some newer studies suggest an influence of different types of prior knowledge on students' academic success depending on the study domain.

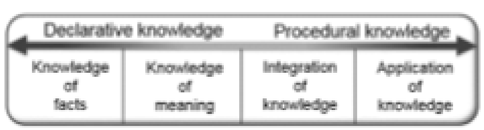

Figure 1: Types of prior knowledge according to Hailikari (2009)

Hailikari (2009) developed a model (Fig. 1) that divides prior knowledge into four different types: knowledge of facts (KOF), knowledge of meaning (KOM), integration of knowledge (IOK) and application of knowledge (AOK). These types are derived from Bloom's revised Taxonomy of Educational Objectives (Anderson & Krathwohl, 2001). While KOF is defined as recognizing, enumerating, recalling or remembering the basic elements of a discipline (i.e. facts), KOM is defined as reproducing or understanding the interrelationships among those basic elements (i.e. concepts) (Hailikari, 2009, Anderson & Krathwohl, 2001). IOK and AOK are knowledge types with a far more procedural character (Hailikari, Nevgi & Lindblom-Ylänne, 2007). For IOK the interrelations and comparison of the disciplines concepts is required and AOK demands an implementation of knowledge for problem solving (Hailikari, 2009).

While different predictive power of the knowledge types could be shown for mathematics, pharmacy, and chemistry (Hailikari, 2009), evidence for their impact on biology and physics academic success is still missing. We take this up in our project, which investigates, to which degree academic success in the first year is predicted by these types of knowledge in biology and physics. Especially, we are interested in varieties of the predictive power of different types of prior knowledge in different domains. These aims lead to the following research questions:

1) To what extent does subject specific prior knowledge predict study success in biology and physics?
2) To what extent do different types of prior knowledge predict study success in biology and physics?
3) Is academic success predicted differently by the four prior knowledge types for biology versus physics students'?

RESEARCH DESIGN AND METHODS

Based on their specifics each type of knowledge needs to be assessed with different assessment methods (Dochy & Alexander, 1995). In order to analyse the impact of the four types of knowledge, first test drafts were developed for biology and physics in each type of knowledge. Using these tests, we will assess students' knowledge at three points of time during their freshman year. To assess KOF, multiple-choice single select tests were designed, consisting of 62 items for biology and 43 items for physics.

To assess KOM short-answer tests were constructed, one for biology and one for physics, consisting of 15 items each. The respective items assess the students' understanding of the fundamental concepts of the subject. IOK is assessed with a concept mapping task. For AOK we use so called sorting tasks. According to Friege and Lind (2006) these specific tasks assess problem scheme knowledge in a more economical way than traditional problem solving tasks. All tests will be administered to biology or physics students' three times during their freshman year. The items refer to knowledge from high school and university level to fit the abilities of the students at the beginning and at the end of the first year. Our dependent variable, academic success, is operationalized through continuance in studying, student achievement, and subject-specific knowledge gains. At the current project stage data for the first point of measure have been collected and are currently analysed. Depending on how the tests will be constructed for the following points of measurement, knowledge gains can be assessed by means of longitudinal Rasch modelling or correspondence analyses.

The main benefits of the project will be deeper insights into the individual prerequisites of successful students in biology and physics. In addition, the project will allow for analyses of correlations between academic success and subject-specific factors as well as general factors. The project's findings can be used to develop subject-specific tests for university admission and to improve study conditions. The ESERA Summer School would provide a great opportunity to discuss further appropriate methods for our data analyses.

PRELIMINARY FINDINGS

At the current project stage data of the first point of measuring have been collected and are being analysed. Therefore, a longitudinal analysis of the students' types of knowledge is not available yet. Hence we can only report statements about the test quality and the students' prior knowledge so far:

Both multiple-choice tests for KOF show good reliabilities (biology: $\alpha = .81$, physics: $\alpha = .82$). In biology the test results reveal differences between the two biological topics tested. Especially KOF items with a zoological topic ($M = 0.36$, $SD = 0.17$) seem to be difficult. These items are significantly more difficult ($t(81) = 4.00$, $p < 0.01$, $d = 0.38$) than KOF items with a botanical topic ($M = 0.41$, $SD = 0.13$). This result implies that students remember more facts about botany and botanical physiology, than about zoology. Furthermore, the knowledge about botany seems to be better integrated in students' knowledge structure. Parts of the concept maps with mainly botanical concepts ($M = 0.55$, $SD = 0.16$) are interlinked significantly higher than parts with mainly zoological concepts ($M = 0.51$, $SD = 0.15$) ($t(88) = 2.35$, $p < 0.01$, $d = 0.29$). In physics no differences in knowledge of facts can be found between the topics mechanics and electrodynamics. Even though the concepts in electrodynamics ($M = 0{,}54$, $SD = 0{,}15$) are significantly less integrated ($t(49) = 2{,}34$, $p < 0{,}1$, $d = 0{,}18$) than concepts in mechanics ($M = 0{,}57$, $SD = 0{,}16$). The less known topics may be a mayor stepping-stone for academic success in the freshman's year. This conclusion can only be tentative, without all data being analysed. Findings on the other types of knowledge and on academic success will be available for the presentation.

PARTICULAR ISSUES OF THE PROJECT

With the pilot studies just having started, the ESERA summer school will be an ideal place to discuss my first results with a team of doctoral students and collect suggestions for the main study (starting October 2016) regarding the longitudinal data analysis and further improvement of the tests. I am especially interested in ideas regarding the longitudinal analysis of the concept maps and the sorting tasks. I would be delighted to present my project and the particular instruments to other researchers and collect suggestions for improvement.

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USING INCORRECT REPRESENTATIONS TO ENHANCE THE UNDERSTANDING OF ENERGY IN BIOLOGY

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TOPIC

Energy is an abstract concept of immense relevance to all natural sciences. Additionally, energy has great social relevance: For example, increasing renewable energy usage in order to ensure future energy supply is an important task for our society. For the energy transition to succeed public acclaim is regarded as highly important (World Energy Council, 2015). Therefore, energy is an important topic in school education. Due to its abstractness, teaching and learning the energy concept is a great challenge. A variety of studies showed that students as well as teachers have a limited understanding of energy (Duit, 1984; Opitz, Harms, Neumann, Kowalzik, & Frank, 2015) and that several misconceptions exist (e.g. for biology: Burger, 2001). In my doctoral thesis I aim to enhance students' understanding of energy by use of representations. The present intervention study tests the effect of an innovative instructional tool for biology education that is meant to foster the understanding of energy. The instructional tool combines two teaching strategies: Learning from errors and learning through representations.

THEORETICAL BACKGROUND

Educational research hypothesizes that errors can be used constructively in the learning process. Reflecting on errors leads to the acquisition of so-called negative knowledge, knowledge about how something is not in contrast to how it really is (Oser & Spychiger, 2005). As research in mathematics education demonstrated, reflection on incorrect examples can have a positive effect on knowledge acquisition (Durkin & Rittle-Johnson, 2012). Students with poor prior knowledge benefit from errors already highlighted (Große & Renkl, 2007). These insights were used to develop an instructional tool to foster the understanding of energy. At the same time the instructional tool is based on external representations. Recently, several studies have provided evidence that the use of external representations can support students in grasping abstract concepts by visualizing phenomena that cannot be seen by the human eye (Ryoo & Linn, 2012). Energy flow through an ecosystem was chosen as the topic for the intervention. Research provides evidence that students possess strong alternative conceptions regarding energy flow. This forms a good basis for inserting reasonable mistakes into a representation.

HYPOTHESES

Based on the findings of mathematics education research, we expect that learning with an incorrect representation better supports the understanding of energy than learning with a correct representation (Hypothesis 1). Moreover, taking the relevance of prior knowledge into account, we hypothesize that assisted learning with an incorrect representation (i.e., the error is already encircled) benefits students with low prior knowledge (Hypothesis 2a). These students might not be able to find the error by themselves. By contrast, learners with high prior knowledge are not assumed to benefit from highlighted errors (Hypothesis 2b); the marking might discourage their thoroughly examining each part of the representation.

RESEARCH DESIGN AND METHOD

An intervention study with a 2 × 3 pre-posttest design tested these hypotheses. The three groups differed in the received learning material composed of a diagram showing energy flow through a forest ecosystem and associated tasks (see Table 1). Pre- and posttests assessed students' understanding of energy. From September to December 2015, *N* = 310 ninth graders from 12 academic track schools ("Gymnasium") in Northern Germany participated in the study.

The intervention started for all groups alike with a standardized lecture on energy flow in ecosystems intended to refresh students' knowledge. Afterwards, students worked independently on the learning material. The error inserted into the incorrect versions of the energy flow diagram targeted widespread alternative conceptions: It was an additional arrow pointing from the decomposers in the soil to the producers, thus suggesting (1) that plants get part of their energy from the soil and thereby (2) that energy, just like matter, flows in a circle and can be recycled (Burger, 2001). Three versions of the diagram were designed and complemented with tasks (see Table 1).

Group 1	Group 2	Group 3
Incorrect representation, without aid	Incorrect representation, with aid (error already encircled)	Correct representation
• identify the error		
• explain the error	• explain the error	
• explain energy flow	• explain energy flow	• explain energy flow

Table 1: Learning Material of the Three Groups

Two weeks before and directly after the intervention, the understanding of energy was assessed. The energy concept test was developed and validated by Opitz et al. (2015). Due to the limited time frame we shortened the test to eight multiple-choice items which are representative of the entire test with respect to context, item difficulty and item discrimination. The test was enriched with 10 more items specifically concerning energy flow which were compiled from a number of sources (Beals, McNall Krall, & Wymer, 2012; Beyer, Remé, & Steinert, 2010; Burger, 2001; Hildebrandt, 2006; Kappei, Mühle, & Lucius, 2009). A pilot study tested the suitability of the learning material, diagram, energy concept test and energy flow test.

Concerning control variables, intelligence (KFT N2 - graphic analogies; Heller & Perleth, 2000), fluency (cloze tests; Wockenfuß & Raatz, 2006), cognitive style (Verbal-Visual Learning Style Rating; Mayer & Massa, 2003), effort (effort barometer; Ramm et al., 2006), and time spent on tasks were measured. Moreover, students completed a form reporting their sex, age, last report-card grade in biology, and their experience with suchlike spot-the-error-puzzles in school.

DATA ANALYSIS

After investigating descriptive statistics with a focus on performance on the diagram tasks, I will examine change in students' understanding of the energy concept within the three groups. Mixed-model analyses of variance (ANOVAs) will be complemented by structural equation modeling allowing for tests of the hypothesized moderation.

PRELIMINARY RESULTS

Contrary to our hypothesis 1, ANOVA indicated no differential improvement of students' understanding of the energy concept between groups, $F(2, 288) = 2.69$, $p = .069$. Strikingly, descriptive statistics showed that only 10.6 % ($n = 11$) of students in group 1 and 27.7 % ($n = 28$) in group 2 solved their respective diagram tasks correctly. Results indicate that these successful students do benefit from learning with an incorrect representation.

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USING DIGITAL STORYTELLING IN BIOLOGY TEACHING

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THEORETICAL FRAMEWORK

Our study focuses on exploring the effectiveness of Digital Storytelling (DS) in teaching Biology in Secondary Education. The sample is consisted of 54 students that is divided into the experimental and control group. In both groups an educational process will take place in thematic sections of Human Anatomy and Physiology during the current school year. The experimental group will produce digital stories using one of the following software: Windows Photostory3, Windows Movie Maker and Microsoft PowerPoint. The control group is going to create digital presentations using Microsoft PowerPoint. Qualitative research methods are going to be used in order to identify the impact of DS on students' engagement and deep learning.

Digital storytelling (DS) is a technology application that "takes the ancient art of oral storytelling and engages a palette of technical tools to weave personal tales using images, graphics, music and sound mixed together with the author's own story voice" (Porter, 2005). In educational practices DS grows in popularity the last years. Educators use it very often (Lowenthal, 2009) as digital stories creation facilitates the convergence of four student-centered learning strategies: engagement, reflection for deep learning, project based learning and the effective integration of technology into instruction (Barret, 2006).

Despite the growing popularity of this technology, there are a number of technological and pedagogical challenges about using DS for educational purposes (Hofer & Swan, 2006) such as the necessary time students need to spend on creating digital stories, training in using software and the connection with the curriculum (Ohler, 2005/2006). Furthermore, DS is most often associated with arts and humanities (Sadik,2008) like the study of Tsou et al (2006) in which it was proved that that integrating DS into the language curriculum can improve students' level of learning in reading, writing, speaking and listening. Although there is a special type of digital story which is used in content areas such as science that Robin (2008) calls "Stories that inform or instruct" there is a lack of research in this area. There are few relevant studies that suggested that DS can be used to teach computer science and programming or algorithms to a wider and more diverse audience (Papadimitriou, 2003 and Schiro, 2004). The effects of integrating DS on students' engagement and learning achievements have not been fully investigated in the area of Sciences and specifically in Biology. Thus our research aims to explore the impact of DS on students' learning in Science and subsequently to contribute to the discussion on how and why DS facilitates deep learning.

Engagement and motivation are key factors in successful learning (Hung, 2012). The application of technology improves students learning motivation and performances in technology-rich classrooms (Jonassen, 2000). However instructors need to design meaningful activities for enhancing students' interest and promoting active learning (Chang, 2005) in order to actively interpret and comprehend the knowledge (McLellan, 1993). Creating a digital story could be a meaningful activity for students as it provides them the chance to express their personal opinion on a subject or explore in their own way a physical phenomenon or procedure (Blocher, 2008). Taking into consideration the aforementioned we developed and applied in our study educational material that is characterized by two basic characteristics; the use of several multimedia resources like images, video and text as well asd the connection of the educational content with everyday life problems. At the end of each thematic session students are assigned with individuals tasks; they develop either a digital story or a presentation about a specific health problem that address by exploring possible causes and solutions.

RESEARCH QUESTIONS

This study aims to provide answers to the following questions:

1. Whether and how digital storytelling promotes students' engagement in Biology learning tasks?
2. Whether and how digital storytelling promotes students' understanding in basic Biology concepts?
3. Whether and how digital storytelling promotes students' deep learning in Biology?

RESEARCH DESIGN

Data collection begun in November of 2015 and is planned to be completed by September of 2016. The sample consists of 54, 15 years old Greek students in Upper Secondary Education and is divided in an experimental and control group. In both groups the same thematic sections will be taught in Biology: Nervous, Sensory, Circulatory, Reproductive Systems, and Glands and Hormones. According to the present Greek curriculum in Upper Secondary Education the Biology course is two hours teaching weekly. Thus, our study is scheduled to cover 40 teaching hours on a year base. The students of the experimental group construct a digital story. A preliminary lesson took place to familiarize these students with the software tools. The control group creates presentations using PowerPoint; At the end of each thematic section students are assigned with individuals tasks; they develop either a digital story or a presentation about a specific health problem that address by exploring possible causes and solutions. For example student worked on the symptoms and causes of meningitis or Parkinson disease when they studied the Nervous System.

In our study we use qualitative field research methods that referred as techniques or strategies that seek to observe, describe and interpret activities, events and individuals in their natural settings (Blomberg et al 1993) In order to investigate the impact of DS in the learning process we use the following research tools:

a) Questionnaires. At the end of each section students complete a self- assessment questionnaire that contains open questions concerning the way they worked and the problems they faced during the development of either digital story or presentation.
b) Knowledge Test: At the end of each section students complete an assessment test that contains both closed and open questions to check students' reflection on the content. A similar test on September of 2016 as a late post test will assess students' capability to recall knowledge and to explain and synthesize basic Biology concepts.

c) Research Diary. According to Silverman (2005) the diary is to report decisions made and the thinking process on methodology. It is an internal dialogue and reflection that becomes part of the research data and can inform the research interpretations. The research diary also gives more validity and credibility to the data because it checks and triangulation, provided scaffolding tools (Gerstl-Pepin & Patrizio, 2009) to support researcher's work.

d) Students' Digital Products. Both groups' digital products are going to be analyzed in order to study: a) students' knowledge (relevance to the task, specificity of answers, correct answers) b) deep learning (students synthesize information to develop their own solutions, express novel ideas, pose new questions, express personal opinions) and c) engagement (use of multimedia resources and combinations of them, searching of information, students' references)

e) Students' interviews. At the end of school year both in person and in group discussions students' interviews are going to be conducted in order to investigate how students comment their learning process and to evaluate DS impact in engagement.

PRELIMINARY FINDINGS

Up to present each student participated in this study has already completed two digital stories. From the self assessment questionnaires it is clear that students in the experimental group believe that developing digital stories makes the lesson "less boring" and close to real life problems. Students of the control group also believe that developing their own presentations made them understand the connection with real life problems but they don't make any comments if they find it more interesting or not. There preliminary findings arise one a main concern about the way learning tasks influences students' engagement.

It was revealed that students of the experimental group made enriched descriptions, gave emphasis on the symptoms of the diseases they usually discuss and searched for alternatives ways of therapy. For example, while studying Parkison disease some students in this group searched for famous actors that suffered from it and used their story to explain the symptoms and the effect of Parkinson disease on these people everyday life. They also referred to possible new therapies for this disease making connections with the causes. On the other hand students of the control group used presentations to show the symptoms (using bullets) or the solutions without making any cognitive connections.

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TEACHING ABOUT THE NATURE OF SCIENCE AND SCIENTIFIC PRACTICES THROUGH LABORATORY WORK

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INTRODUCTION

Nature of science is considered a crucial aspect of scientific literacy. Calls for including nature of science in the curriculum is often aligned with calls for an authentic science education (Wong & Hodson, 2009). In the research literature, Shaffer and Resnick (1999) identified four different meanings of authentic education: learning that is personally authentic to the learner, learning that is authentic in relation to the real world outside the classroom, learning that is authentic in relation to a particular discipline and learning where the means of assessment are an authentic reflection of the process itself. According to Knain (2015), the discipline-authenticity can be defined in terms of vision 1 purposes of science education. Real-world authenticity, on the other hand, can be defined in terms of vision 2 purposes. The science education landscape is characterized by two broad visions of scientific literacy; vision 1 and vision 2. These visions have roots in two conflicting curriculum sources. Vision 1 have roots in the discipline of science itself. Vision 2, on the other hand, have roots in situations in which science plays a role in human affairs (Roberts, 2011).

Laboratory work has played an essential role in science education for over a century, but has often been criticized for portraying a misleading image of science. My project is a design-based project that aims at designing authentic laboratory activities and develop instructional material to support teachers in implementing authentic laboratory work. I will primarily focus on discipline-authenticity; the laboratory activity should reflect an authentic view on nature of science.

LITERATURE REVIEW

The importance of laboratory work has been questioned due to a lack of research confirming its effectiveness (A Hofstein & Lunetta, 1982; Hofstein & Lunetta, 2004). Still, many researchers believe that meaningful and distinctive learning is possible in the laboratory, but that science teachers have not utilized this environment effectively (Avi Hofstein & Lunetta, 2004). For instance, the laboratory is a setting where scientific argumentation and nature of science can be taught effectively (Kind, Kind, Hofstein, & Wilson, 2011; Hodson, 1996). However, several studies show that this is not a part of common practice in the laboratory which is rather to let the students follow very precise instructions about methods and analysis given by the teacher (Tiberghien & Veillard, 2001; Newton, Driver, & Osborne, 1999). This recipe-based way of teaching in the laboratory portrays a misleading image of science (Driver, Newton, & Osborne, 2000). Hodson (1996) have criticized how different approaches to learning about scientific methods in the laboratory such as discovery learning, problem-based learning and constructivist approaches, have misrepresented nature of science. If one of the aims with laboratory work is to teach about nature of science, it must at least be based on a view of science that is philosophically sound; it must be authentic to the discipline of science.

There are some disagreements among scientists, sociologist and philosophers of science about what constitutes nature of science. However, these disagreements are to a large degree irrelevant to science education, according to Lederman (2007). There are some domain-general characteristics:

- Science is empirically based.
- Scientific knowledge is tentative and subject to change.
- Scientific knowledge is theory-laden and relies on (partly subjective) inferences.
- Creativity plays an important role in the generation of scientific knowledge
- Science is socially and culturally embedded.

This list of characteristics has been referred to as the consensus-view of nature of science (Erduran & Dagher, 2014). The consensus-view have led to a lot of empirical research. This research shows that both students and teachers lack a sophisticated view of nature of science. Also, it shows that such issues need to be addressed in a reflective and explicit manner in order to be taught effectively (Lederman, 2014). However, the consensus-view has been subject to some critique. For instance, Elby and Hammer (2001) argue that such generalizations about nature of science introduced out of context do not lead to a sophisticated understanding of nature of science. Further, they argue that items within nature of science ought to be elucidated in relation to one another in 'authentic contexts'.

In response to these discussions about nature of science, Erduran and Dagher (2014) provides a flexible and holistic framework of nature of science. The framework is divided in two main aspects: the cognitive-epistemic system and the social-institutional system. The framework has open-ended categories and they thereby invite other science educators to contribute in the discussions about the teaching and learning of nature of science. My project will hopefully be a contribution in this discussion.

Wong and Hodson (2009, 2010) argue that scientist who work at the frontiers of science can play an important role in refining science educators´ views about nature of science. This may be particularly relevant in rapidly growing fields such as molecular biology. Wong, Kwan, Hodson and Yung (2009) conducted a case-study on key scientists involved in research on severe acute respiratory syndrome (SARS). This authentic context illustrated vividly some features of nature of science. Based on this case-study, instructional material was developed. This contemporary real-life context was found effective in promoting student teachers understanding of nature of science. This study has been an inspiration for my project.

According to Wellington and Osborne (2001), learning the language of science is maybe the most important achievement the students can do. However, the meaning-making practices of science includes both visual, actional and linguistic modes (Kress, 2001). This may be particularly truth when it comes to laboratory work where the students are active, read instructions, observe and draw conclusions. Wallace (2004) holds that successful learning has taken place when the language of science is used in a personally meaningful way. During laboratory work, students often feel ownership to their own collected data and this may make it more authentic and lead to increased learning. Therefore, focusing on personal authenticity as well as discipline authenticity is probably important for students learning.

The following overall research question guides my project:

1. How can authentic laboratory activities be designed in cooperation with a practicing scientist?
2. How can teachers be supported in carrying out authentic laboratory activities?

METHOD AND PRELIMINARY RESULTS

This design-based project aims at developing instructional material for an authentic laboratory course. The aim with this material is to support teachers in performing authentic laboratory work. Figure 1 shows an overview over the project.

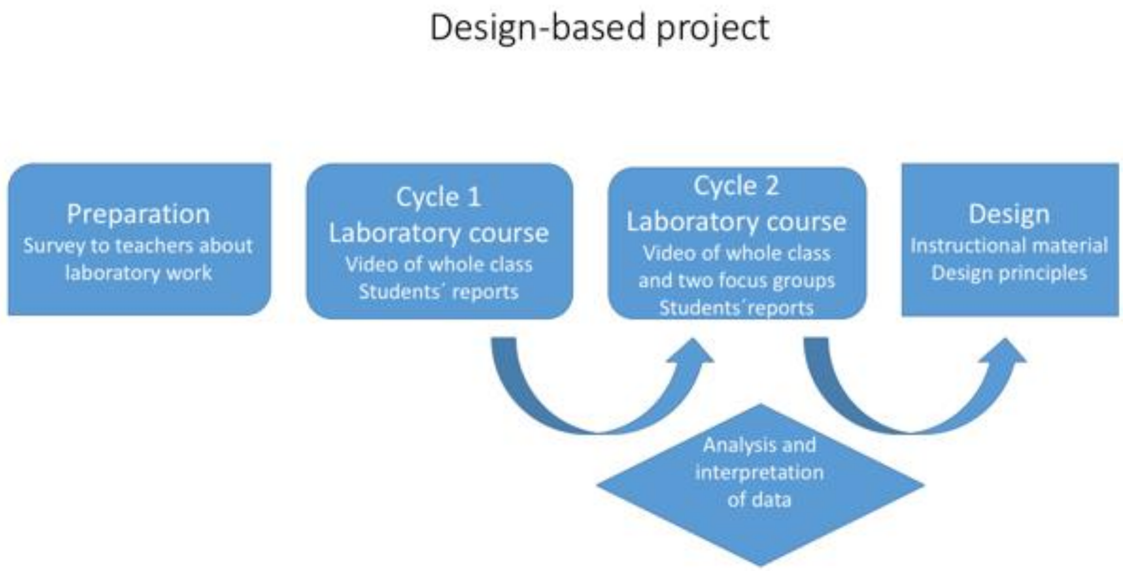

Figure 1: overview over the project

Preparation for the experiment

Since the aim with the project is to design instructional material for teachers we wanted to know more about Norwegian biology teachers´ practices and challenges when it comes to laboratory work as well as their educational background. Even though there are a lot of knowledge about teachers´ practices in the laboratory, we wanted to know more about this from the teachers´ perspective. Therefore, a large survey including open-ended questions answered by biology teachers in Norway was analysed. Thematic analysis was used and the following research questions guided the analysis:

1. What are teachers reported practices and challenges when it comes to laboratory work?
2. What implications can we draw from these reported practices and challenges in the design of instructional material?

Preliminary analysis of survey results:

The analysis shows that many Norwegian biology teachers have experience with authentic laboratory work as part of their biology education. However, when teaching in the laboratory in school they often use a recipe-based approach and focus solely on conceptual learning. Some reported reasons for this are practical hindrances such as large classes, and pressure towards exams. Also, many teachers highlight that knowledge about laboratory work in the school setting is something that was missing from their education. It seems like they have challenges in transforming the experience from their own authentic research experience into the school setting.

The authentic laboratory course

A specific undergraduate laboratory course was chosen as a starting point for the design-based project. This course is not chosen arbitrarily. Because it is designed and taught by a practising scientist, I believe it has some potential for reflecting nature of science authentically. Also, even though this course was taught at the university, it has potential for being taught as a laboratory course in secondary school. Further, the course portrays a potential for being personally relevant for the students because it is an actual investigation of different diagnostic tests available in pharmacies. The laboratory course is a five hour activity with an introductory lecture first. There are over 40 students in the laboratory at the same time and they work in pairs. The theme for the course is immunology, anti-bodies and their commercial use.

Cycle 1

In the first cycle, the laboratory course was analyzed as it was designed by the professor. The aim with the analysis was to identify authentic aspects that could be made more explicit. The following research questions focused the analysis:

1. Which aspects of nature of science are reflected in the laboratory course?
2. How (in which modes) are these aspects of nature of science visible during the laboratory course?

I used whole-class video-cameras with microphone on the professor. Erduran and Dagher´s (2014) framework of nature of science was used to identify and explore aspects of nature of science addressed in the teaching. The focus for the analysis was on the full repertoire of meaning making resources brought to the classroom (Kress, 2001). Also, an interview with the professor was conducted to discuss these aspects further. Students´ reports were collected and analyzed to study how these aspects were reconstructed by the students.

Preliminary analysis of cycle 1:

Several aspects of nature of science were reflected in the teaching program and they were reflected through several modes. For instance, social-institutional aspects of science, such as financial and economical aspects, were an important part of the context for the laboratory task. These aspects of nature of science should be given more attention in order to educate scientifically literate citizens according to Erduran and Mugaloglu (2013). Also, these aspects of nature of science were partly reflected in the design of the activity as a “consumer-test”. Students actions were thereby directed towards typical scientific practices such as designing experiments, observing, interpreting results and so on (Erduran & Dagher, 2014). Further, there was an extensive use of representations by the professor and some of these representations were visible in students´ reports. Before the next cycle, I suggested a more exlplicit connection between aspects of nature of science and the design of the activity. Also, I suggested a more explicit representational focus to increase students learning.

Cycle 2

One year later and with a new group of students, I followed the laboratory course again. This time head-mounted cameras on two focus-groups of students were also used in addition to the whole-class camera. This is because I wanted to analyse in more detail how the students worked during the inquiry and how they worked with representations in the laboratory report. The focus for the analysis of this cycle, will primarily be on students learning. The dialogues between the students and between the students and the professor will be analysed. Also, the reports from the first and second cycle will be compared.

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INCORPORATING NATURE OF SCIENCE INTO PRE-SERVICE SCIENCE TEACHER EDUCATION

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DEFINING THE PROBLEM

The importance of including Nature of Science (NOS) has recently been addressed in the reform of the Junior Cycle (middle school) Science curriculum in Ireland, where the NOS theme is an overarching feature of all teaching and learning in the curriculum document (NCCA 2015). This is the first time this objective has been a focus of science curricula in Ireland. Addressing NOS is now a key concern for initial teacher education programmes in Ireland, as it will be pivotal to its successful incorporation in the science classroom. Added to the local context, there is broader milieu where research shows teachers and students continue to hold naïve views of NOS (Abd-El-Khalick & Lederman 2000, Wahbeh & Abd-El-Khalick 2014). To improve this understanding, teachers need to be provided with the time to explicitly plan to teach NOS where they provide an opportunity for discussion and reflection on and specifically assess the development of their students' conceptions of NOS (Abd-El-Khalick & Lederman 2000, Lederman *et al* 2001, Wahbeh & Abd-El-Khalick 2014).

To address NOS in initial science teacher education, a two phase study is being conducted. The first phase designs and facilitates a purpose built workshop aimed at supporting the development of pre-service teacher's (PSTs) NOS conceptions. The programme will be theoretically based on an NOS model derived from the Family Resemblance Approach (FRA) which highlights science as a cognitive-epistemic and a social-institutional system (Erduran & Dagher 2014). The strategy will involve the PSTs developing Formative Assessment Classroom Tasks (FACTs) that incorporate NOS. FACTs are to be used for in class work, homework or even a summative test, to inform and assess their student's knowledge and understanding of NOS, or as summative test. While learning about NOS in the two-hour workshops, the PSTs develop FACTs to cement their own learning in their own time before the next workshop. These were to be uploaded to an on-line platform where the author reviewed and provided feedback by the next workshop. The approach will be an explicit-reflective approach, where participants will have an opportunity to learn how to embed NOS content in their lessons (Abd-El-Khalick and Lederman 2000, Schwartz *et al* 2004). The second phase will involve observations of the PSTs in a lesson while on teaching practice, utilising the FACTs they developed in the first phase in the science classroom with the aim to see if they have sufficiently developed NOS concepts to promote the learning of NOS in their students. As this is a voluntary study, PSTs participation varied throughout, and ranged from 26 participants (pre-test) to four participants (post-test).

LITERATURE REVIEW

Developing NOS understanding is one of the most commonly stated objectives for science education, as a central component of scientific literacy is having an adequate understanding of the 'Nature of Science' [NOS] (AAAS, 1990, 1993, Klopfer 1969). The literature highlights justifications for its inclusion in science education which include the facilitation of increased understanding and interest in science, and offers the broader perspectives of science then those currently present in science curricula and textbooks (Leden *et al* 2015). Consequently, to effectively teach about NOS, teachers need to have more than a basic knowledge and understanding of some NOS aspects (Abd-El-Khalick and Lederman 2000). They need to know a range of related examples, demonstrations, and historical episodes. However there are diverse views as to what constitutes NOS. Lederman *et al* (2002) argues that there are many disagreements about the specific definition of NOS that are irrelevant for K-12 instruction that is shared amongst the philosopher, historians, sociologists, and science educators. The view of NOS underpinning this research is the theoretical framework of the Family Resemblance Approach (FRA). The FRA was chosen for this research as it assumes a comprehensive and systematic approach and provides a novel way of capturing the unity of science while doing justice to its diversity (Erduran & Dagher, 2014).

Family Resemblance Approach

The basic idea of Family Resemblance likens science to the fact that the member of a family can each resemble one another in some details but not others (Irzik & Nola 2014). The views of Irzik & Nola (2014), while based on Wittgenstein's work, is in opposition to the "consensus view", arguing that it is an alternative that is more comprehensive and systematic (Irzik & Nola 2014). Their work was further developed by Erduran & Dagher (2014) in the development of the FRA wheel (see Figure 1) which identifies science as a cognitive-epistemic and social-institutional system. Science as a cognitive-epistemic system occupies the centre divided into four categories. This circle floats within a larger concentric one also divided into four quadrants, pertaining to the four components of science as a social-institutional system. Although the representation uses divisions to illustrate the various components, the notion that all of the cognitive, epistemic and social-institutional components co-exist as a whole, provides a departure from representing science relative to particular discrete set of ideas. The boundaries between the compartments are perforated, indicating the non-compartmentalised nature of the components (Erduran & Dagher 2014). This image transforms Irzik & Nola's (2014) tabular format to a concentric circle model. This aims to enhance the depiction of science as a holistic, dynamic, interactive and comprehensive system, subject to multiple influences and affects (Erduran & Dagher 2014).

Figure 1: The FRA wheel representing science as a cognitive epistemic and social-instructional system

Application of teacher education models

Successful models of teacher education will be used to structure the development of PSTs knowledge of NOS through FRA. The programme aims to target a number of areas from Shulman's framework for teacher knowledge. These include science content knowledge, general pedagogical knowledge, curricular knowledge and pedagogical content knowledge (Shulman 1987). This study aims to develop the teachers NOS content knowledge and NOS pedagogical content knowledge. If the PSTs are to incorporate NOS into their science lessons, they need to be motivated and find NOS worthwhile to teach, as well as graspable for students (Leden *et al,* 2015). This programme aims to therefore provide PSTs with the platform to develop the motivation, efficacy, content knowledge and pedagogical content knowledge (Lederman *et al* 2001).

Formative assessment approach

It is well known practice in education that a students' ability to formulate good questions about topics can indicate the extent to which a student understands the topic, especially when they have to devise questions which go beyond recall (Black & Wiliam 1998, Keeley 2008). This rational is used in this study to (i) assess that the PSTs concepts of NOS have developed, (ii) have NOS teaching materials readily available and (iii) so they have an understanding of formative assessment.

RESEARCH QUESTIONS

The study aims the answer the following questions:

1. How will the Family Resemblance Approach (FRA) model impact the development of pre-service teachers' knowledge of Nature of Science (NOS)?
2. What elements of the process of developing the Formative Assessment Classroom Tasks (FACTs) help the pre-service science teachers develop their understanding of NOS?
3. What impact will participation in the study have on the pre-service teachers' retention of NOS knowledge and understanding?

OUTLINE OF THE RESEARCH DESIGN AND METHODS

The research will use case-study research design where an in-depth study will be carried out on the participants involved. This design is useful for testing and drawing conclusions to assess whether the model can be applied to teacher education. The two phased study consists of an intervention where students will voluntarily participate in six two-hour workshops. Outside the workshops the PSTs develop FACTs based on the ideas they learned in the workshops. These are uploaded to an on-line platform and reviewed and feedback was provided by the next workshop. The second phase of will involve observations of the PSTs in the classroom using the FACTs they have developed from phase one.

Data collection used in the study includes a questionnaire (design specifically around the FRA) used for pre-, post- and delayed-post-testing, interview and any artefacts generated by the PSTs throughout the study. The main phases and data collection methods are outlined in Table 1 below. Content and Thematic analysis will be conducted on all the artefacts collected

Phase	Activity (and participant numbers)	Data collection tool	Data analysis
Phase 1	Pre-test (26)	Written answers to questions on pre-test, using qualitative and quantitative questions	Statistical packages Nvivo and SPSS used for analysing qualitative and quantitative responses.
	Workshops (15-2)	Digital recording of the two-hour workshop.	Thematic and content analysis using statistical package Nvivo.
	FACTs	Written work and activities undertaken and designed by PSTs	Thematic and content analysis of written artefacts using the statistical packages Nvivo.
	Post- test (4)	Written answers to questions on post-test, using qualitative and quantitative questions.	Statistical packages Nvivo and SPSS will be used for analysing the qualitative and quantitative questions
	Semi-structured Interviews (4)	Digital recording of verbal responses to interview.	Thematic and content analysis of interview using statistical package Nvivo.
Phase 2	Lesson Observation (4)	Digital recording of lesson, lesson plans, any material produced for the lesson and post lesson reflection.	Thematic and content analysis of the lesson and written artefacts using the statistical packages Nvivo.
	Post lesson – interview (4)	Digital recording of verbal responses to interview.	Thematic and content analysis of interview using statistical package Nvivo.
	Delayed-post-test (4)	Written answers to questions on the delayed-post-test using qualitative and quantitative questions.	Statistical packages Nvivo and SPSS will be used for analysing the qualitative and quantitative responses.
	End of study interview(4)	Digital recording of verbal responses to interview.	Thematic and content analysis of interview using statistical package Nvivo.

Table 1: Phased intervention and data collection and analysis methods

These phases will use the explicit-reflective approach, learning-as-conceptual-change approach (Wahbah and Abd-El-Kalick 2014) and using epistemic approaches to develop the PSTs understanding and knowledge of NOS. Both these practices are the cognitive and discursive activities that are targeted in science education to develop epistemic understanding (e.g. Sandoval *et al* 2000, Shulman 1987).

PRELIMINARY FINDINGS

Preliminary findings indicate that the PSTs displayed degrees of conceptual change around a range of NOS ideas, as evident from the pre- and post-test. Following the workshops, all stated they had greatly changed their perception that science is "*clean cut, black and white*", and in how they now see science in their own learning and future teaching. Early analysis indicates that (1) FRA is a suitable theoretical model to scaffold NOS education and (2) the utilisation, implementation and development of FACTs enhances PSTs NOS conceptual knowledge and understanding to engage PSTs with the process of building their NOS PCK. Indication of conceptual change after a comparatively short period of time is a good indicator of the impact of this model for increasing pre-service science teacher conceptions of NOS.

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SESSION C: CHEMISTRY EDUCATION

RESEARCH PROJECT: CONTEXT CHARACTERISTICS AND THEIR INFLUENCE ON STUDENTS' SITUATIONAL INTEREST AND UNDERSTANDING IN CHEMISTRY EDUCATION

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OUTLINE

The decreasing interest of students in chemistry at school is still a problem science education has to worry about (Potvin & Hasni, 2014). One reason for this could be that students often are unable to connect scientific content knowledge with their individual and social lives (Barmby et al., 2008). One response to this initial situation has been the implementation of out-of-school contexts in science learning. The central aim is to awake and to hold students' interest by using contextual settings, which hence, should lead to higher understanding and better cognitive outcomes. Although, many studies give evidence for the positive effects of context-based learning on students' interest, it is still unclear which particular characteristics a context should have to reach these aims.

THEORETICAL BACKGROUND

According to Gilbert (2006) a context is a focal event, which refers to students' living environment. From this setting, problems can arise that need particular content knowledge to be solved. Previous research gives evidence that context-based learning environments show positive effects on affective variables like situational interest. However, results regarding cognitive performances and learning outcomes are rather ambivalent (Benneth, Lubben & Hogarth, 2007; Ültay & Çalik, 2012).

In order to evaluate context-based learning environments it is necessary to measure students' situational interest while learning. Situational interest is defined as a psychological state within a specific situation, which can result from the individual interest of a person or a *situation's interestingness.* When developing learning environments only the situation's interestingness can be varied by using different contextual factors (Krapp, 1999). According to Schiefele (1992), the most important characteristics of this concept of interest are *feeling-related* and *value-related valences*. Feeling-related valences essentially represent the basic needs of the 'Self-Determination-Theory' (Deci & Ryan, 2002), which are autonomy, competence and relatedness (Krapp, 2002). Furthermore, value-related valences refer to the personal importance of a topic. The results of large-scale interest studies show that traditional science education often fails to achieve students' basic needs and to demonstrate the importance of a scientific topic. Hence, these learning environments often are not capable of generating students' situational interest. Context-based learning environments can be a tool to counter this lack of interest. They embed a scientific content in an out-of-school situation, which is supposed to catch students' situational interest. However, looking at the results of the SAS- and ROSE-study (Sjøberg & Schreiner, 2010), it becomes obvious that students' interest in science depends on the chosen context. Although, there are many characteristics stated in the literature, which should be considered, when designing context-based tasks, there is few empirical evidence for their effects on students' motivation and interest. Thus, van Vorst (2013) provides a framework that summarizes characteristics of context-based tasks. The author has investigated the impact of different context characteristics on the feeling-related and value-related valence of situational interest of ninth-graders in Germany by presenting them 24 context-based introductory texts. These texts differed in the characteristics of *topicality* and *relation to everyday life/uniqueness*. The students had to rate their interest in these different contexts and in learning with these contexts with the help of a questionnaire. One of the most remarkable results was that students preferred unique contexts, which were not related to their everyday life with regard to both the feeling- and the value-related valence of situational interest, whereas no influence of topicality could be found (van Vorst, 2013).

Additionally, Kölbach (2011) could show that effects on students' situational interest in different contexts depend on the underlying content area of a task. She conducted a study in order to compare different chemical contents (*properties of salts* and *water as a substance*) within one real-life context. Kölbach has used worked-out examples as instructional material and measured the situational interest of students in the tasks' topic with the help of a questionnaire. A control-group worked on equivalent material within a laboratory situation without any relation to their real-life. Expectedly, the results of this study show a higher situational interest in the context-based learning tasks than in the laboratory situation for both groups. It is remarkable, however, that even in the laboratory situation students reported about a high degree of interest regarding the content *water as a substance*. It seems that context effects are higher, when a less interesting chemical content is taught.

In addition, contextual tasks are often presented in a problem-oriented way. For this reason, Harbach (2013) compared problem-oriented versus non problem-oriented contextualized learning tasks. One finding of this study was that problem-oriented tasks lead to higher cognitive load. When learners have to decontextualize relevant information from the learning task additionally, this may lead to cognitive overload (Harbach, 2013). Therefore, it can be assumed that contextualized tasks are more beneficial for learning when they are presented in a non problem-oriented way. Based on this theoretical outline a relation between the three variables context characteristic, content area and problem-orientation can be hypothesized. However, this relation has not been investigated, yet.

RESEARCH AIM

Based on the theoretical background the central aim of the study is to combine the relevant variables context characteristic (unique/everyday), content area (interesting/less interesting) and problem-orientation and to analyze their effects on students'

a) situational interest
b) learning outcome
c) cognitive load

DESIGN & METHODS

In order to reach the research aim, the three variables described above are varied systematically in a 2x2x2 task design (Fig.1). For each cell, hands-on learning tasks were developed. Within a pre-, post, follow-up- study with German ninth-graders at secondary schools the students will work on eight resulting tasks. In order to measure the dependent variables, students' situational interest will be investigated after each learning task with the help of a questionnaire (Fechner, 2009; van Vorst, 2013). Additionally, students' perceived item difficulty and their perceived mental effort will be surveyed to measure the level of cognitive load (Kalyuga et al., 1999) when working with the tasks. By comparing the results of pre and post content knowledge tests, the learners' knowledge gains will be determined.

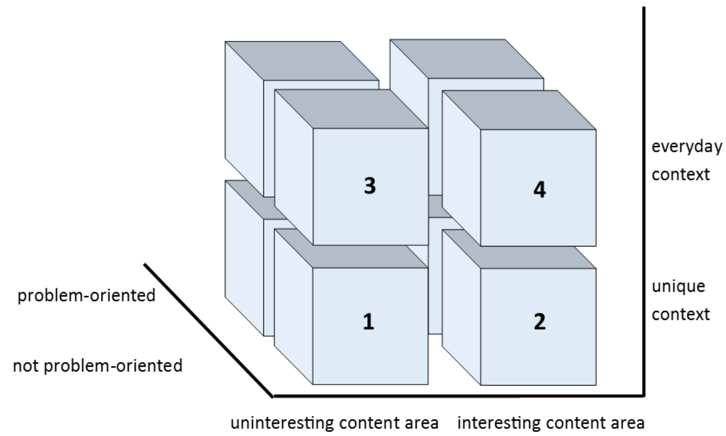

Figure 1: Task-design of the following study

PRELIMINARY FINDINGS

In order to design learning tasks according to the design in Fig. 1, appropriate contextual topics and chemical content areas had to be identified. Therefore, a preliminary study with 435 ninth-graders from German secondary schools has been conducted. The students had to relate 20 different contexts to the characteristics *uniqueness* and *relation to everyday life*. Based on these results, the two contexts *mineral water* (relation to everyday life) and *spouters/volcanos* (uniqueness) could clearly be assigned to the aforementioned characteristics. Additionally, the students had answered a questionnaire about their interest in nine different chemical content areas. The data analyses show that the two content-areas *acids/bases* and *redox* can clearly be assigned to the variables parameter values.

Based on these findings, a pilot study in order to evaluate the developed learning tasks and the used questionnaires for students' situational interest and cognitive load has been conducted. A factor analysis with varimax rotation shows that both the feeling- and value-related valence are described best as two distinct factors. First results support the hypothesis that differing context characteristics affect the two valences of situational interest in a different way: A first data analysis shows that unique contexts seem to be more suitable for maintaining students' interest when learning with more than one contextualized task. More results will be presented at the ESERA Summer School 2016.

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TRANSFER OF KNOWLEDGE IN SITUATED LEARNING ENVIRONMENTS IN THE CHEMISTRY CLASSROOM

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BACKGROUND AND RATIONALE

Several researchers have suggested that formal education has proven unsuccessful in preparing students to apply their knowledge to everyday life (Choi & Hannafin, 1997). Therefore, over the last decades one of the major trend in science curriculum development is the use of contexts and applications of science as a means of developing scientific understanding. The trend of using context-based approaches developed across a number of countries: England, USA, The Netherlands, Canada, Israel, Ireland, Taiwan, Swaziland and Germany (Bennett, Lubben, & Hogarth, 2007). A remarkable variety of research studies focus on the development of students´ interest and motivation and detect a positive effect. In contrast, studies paying attention to students´ understanding of science are limited and result in inconsistent findings (Bennett et al., 2007). In a review of studies on transfer, Dori and Sasson (2013) conclude that, "… too often students fail to apply knowledge and skills acquired in previous learning settings" (Dori & Sasson, 2013, p. 363). This citation emphasizes the problematic transfer of learning. Kortland (2005) notes that in PLON (Physics Curriculum Development Project) "concepts developed within one specific context are not automatically used by students when solving problems in another – known or unknown – context" (Kortland, 2005). The consequence in PLON was to give more attention to the key underlying concepts (Kortland, 2005). This strategy is similar to the strategy used in the German context-based approach *Chemie im Kontext* (ChiK), where "aspects of basis chemical concepts are extracted [decontextualization] and set into relation with prior knowledge" at the end of the unit (Nentwig, Parchmann, Demuth, Gräsel, & Ralle, 2005).

Unfortunately, only a few researchers have addressed the problem of transfer of learning in context-based learning environments. The empirical studies often lack sufficient theoretical background concerning theories of transfer. However, transfer processes from one context to another context remains unclear. Moreover, there is no evidence for the optimal process of extracting concepts from the context (decontextualization) and to embed them into another context (recontextualization) as postulated by context-based approaches. "Transferring knowledge … to novel learning situations depends on the instructional design of the previous situation" (Dori & Sasson, 2013).

In conclusion the goal of this research project is to evaluate to what extent students can transfer chemical knowledge from one situated learning environment to another differentiated by the instructional design of the learning environment.

THEORETICAL FRAMEWORK

In the literature the definition of transfer of learning is consistent: "… the ability to apply cognitive gains from one learning situation to another learning situation" (Dori & Sasson, 2013). Ellis (1965) differentiates three forms: positive, negative and zero transfer. This study focusses on positive transfer of learning which means that "… performance on one task may aid or facilitate performance on a second task …" (Ellis, 1965). However, the forms of positive transfer characterize a wide range of dichotomous terms like *proactive/retroactive*, *active/passive* or *high-road/low-road* (Hasselhorn & Gold, 2009; Lobato, 2003; Salomon & Perkins, 1989). Hence, it is necessary to classify these different forms of transfer. Details on the classification of the transfer expectations of this study will be presented at the ESERA summer school.

For more than 100 years researchers have been focusing on transfer of learning (Barnett & Ceci, 2002). The theories differ because of the orientation and scientific affiliation of the authors (Detterman, 1993). Figure 1 summarizes the research in the field. Depending on the presented context-based approaches the focus of this study is on the third generation of theories. This generation recognizes the unseperability of learning and the context in which it occurs. According to Greeno, Moore, and Smith (1993) "… analyses of transfer focus on structures of activity, considered as interactions of agents in the situations of initial learning and transfer" (p. 161). In summary, the conditions of the third generation theories fit the best with the context-based approaches because situated cognition learning instructions have to be embedded in a learning context (Mandl, Gruber, & Renkl, 1997). "Therefore, a decontextualized approach to technology instruction is unlikely to be successful …" (Bell, Maeng, & Binns, 2013, pp. 350–351). The authors of context-based approaches refer to the theories of situated cognition but also emphasise the importance of a phase of decontextualization. It remains unclear whether decontextualisation could also be achieved by a sequence of several different situated learning situations. Based on presented theories and previous research results, the question arises whether the two-step strategy (decontextualisation, recontextualisation) is necessary to get positive transfer of learning. Consequently, the following research question is formulated.

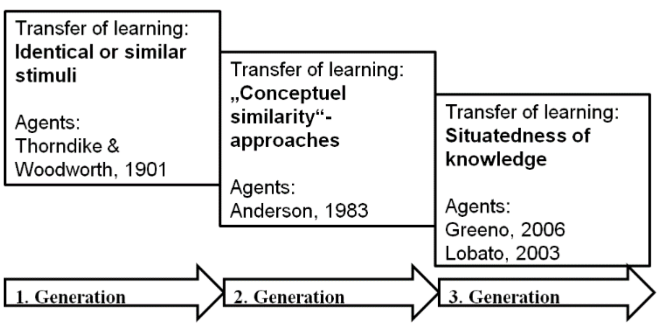

Figure 2: Research of transfer of learning

RESEARCH QUESTION

To what extent can students transfer chemical knowledge from one situated learning environment to another differentiated by the instructional design of the learning environment?

RESEARCH DESIGN AND METHODS

In order to answer the above research question, an experimental study is conducted in a comparison group design. Three groups learn in different experimental learning environments, which deal with the subject matters of acid and base and redox reaction. The learning environments are designed based on the presented transfer theories and the instructions of context-based approaches.

About 200 students will be recruited from eight- grade classes of secondary schools. The pre-test data will be used to divide the sample into three equally powerful groups. Furthermore, the intervention study contains two sessions based on interaction boxes.

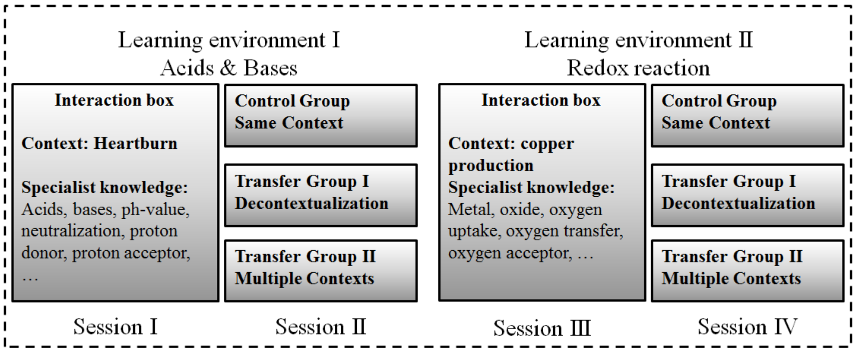

Figure 2: Intervention

While the first transfer group (TG) decontextualises the chemical concepts after the first session, the second transfer group (TG II) works with the experimental learning environment based on a different context. The control group (CG) works in-depth with the same context. This design is repeated in the second learning environment, which refers to a different subject matter (redox reaction). The intervention is accompanied by a modified pre-post design in order to assess students' ability to transfer knowledge between the different contexts (see Figure 3). The modification affects the post-test which partly consists of a hands-on transfer task (videotaped) for selected groups as an addition to paper-and pencil tests.

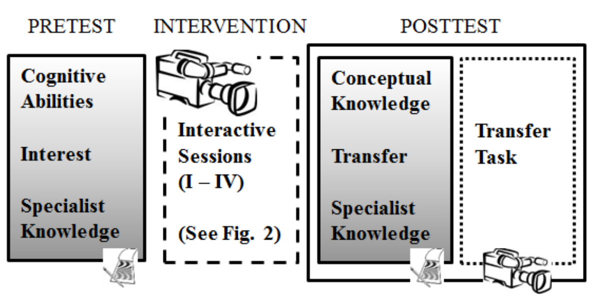

Figure 3: Methods

RESULTS

At the summer school the results of a pilot study will be available as a basis for discussion.

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VISUAL MODEL COMPREHENSION AS A PREDICTOR FOR ACADEMIC SUCCESS IN CHEMISTRY AND ENGINEERING

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RESEARCH GOALS

The comprehension of models is seen as a crucial component for the development of conceptual knowledge in chemistry as well as engineering. In particular, the wide range of applications of visual models in the respective textbooks raises the question of whether, and under which circumstances, such models are beneficial for learning. In this regard, theories such as the Cognitive Load Theory (Van Merriënboer & Sweller, 2005) or the Cognitive Theory of Multimedia Learning (Mayer, 2009) emphasize the importance of instructional design as well as individual learner prerequisites.

My PhD project focuses on predictors of visual model comprehension in chemistry and aims at comparing these with respective predictors in engineering. The project firstly aims at investigating, which forms of visualizations can be found in current basic literature for the university entry phase. It is assumed that for chemistry, while textbooks will include a large amount of symbolic visualizations (e.g., reaction equations), the amount of iconic visualizations (e.g., molecular models) will be even higher. Furthermore, compared to engineering, we assume that in respective textbooks, mainly symbolic visualizations (e.g., circuits, diagrams) can be found.

The different amounts of visual models of different kinds should accordingly lead to a different weighting of the individual prerequisites that serve as predictors for model comprehension in each domain. We expect that for the comprehension of the often iconic and three-dimensional models that can be found in chemistry textbooks, spatial ability will play a crucial role, whereas for the comprehension of the symbolic visualizations in engineering textbooks, mathematical ability will have a bigger impact.

Following insights that will be gained regarding the differential benefits of different visualizations as well as the interaction of instructional design and learner characteristics, a major goal of my project is to build a basic theoretical foundation for the utilization of different visualizations in future instructional materials. As an outlook, the results can contribute to the designing of beneficial learning materials for students with different individual prerequisites.

THEORETICAL BACKGROUND

Contemporary textbooks for university students include an abundance of different visualizations. This can be traced back to the general view that visualizations are important to understand scientific concepts. For instance, Wu and Shah (2004) state that “Chemistry is a visual science”. This view is supported by an own exploratory textbook analysis (Dickmann, T., Opfermann, M., Rumann, S., Dammann, E., Lang, M. & Schmuck, C., 2015) which found that on average, 85% of contemporary university chemistry textbook pages contain visualizations of all different kinds.

Against the background of high university drop-out rates (OECD, 2011), two conclusions can be drawn. First, despite the widely spread usage of visualizations in educational contexts, results on their effectiveness are highly diverse and domain-specific (e.g., Höffler, T., Schmeck, A. & Opfermann, M., 2013). Second, to be able to provide a comprehensive approach to the usage of visualizations in chemistry/engineering, it is necessary to have a look at individual differences between learners and the way they process instructional materials.

In an attempt to draw conclusions from the diverse findings, the particular nature of the visualizations used has been taken into account. According to Schnotz (2002) instructional materials contain different types of visual information, i.e. descriptive/depictive or iconic/symbolic elements, which are processed differently. Icons for instance show a similarity to the object they represent, e.g. a drawing of a molecular model. Symbols, in turn, do not show such similarities; e.g. the word 'molecule' has no similarity to the actual submicroscopic structure of matter.

To sum up, the ability to comprehend and work with visual models/visualizations of different kinds is seen as crucial for study success within different domains. However, while a remarkable amount of research has focused on the question, how instructional materials should be designed, the question what exactly makes up the successful comprehension of visual models has only received little attention so far. That is, visualizations are only assumed to foster learning if learners are able to identify their relevant elements, to "translate" them and to relate them to each other and to their respective textual counterparts. This ability will be called "visual model comprehension" in my PhD project. One major focus of my project is to develop a test that is suitable to assess visual model comprehension for chemistry, engineering as well as on a domain-independent general level. To do so, the first part of the project includes a comprehensive textbook analysis to investigate types of visualizations that are used in contemporary chemistry and engineering university textbooks. In a second step, these findings are used to develop the above mentioned test to assess visual model comprehension. Finally, in the main study, we aim at investigating, whether this kind of visual model comprehension predicts study success in chemistry and engineering and if so, which individual prerequisites, in turn, predict visual model comprehension. As a consequence, insights from my project can be used to support respective abilities and therefore countervail study drop-outs.

RESEARCH QUESTIONS

- RQ1: Which types of visual models / visualizations can be found in contemporary textbooks for university students in chemistry and engineering science, especially at the beginning of studies?
- RQ2: Which individual prerequisites do university students possess at the beginning of their chemistry or engineering studies?
- RQ3: Which of the aforementioned individual learner characteristics predict the successful comprehension of and working with different types of visual models / visualizations?

METHODOLOGY AND CURRENT STATUS

The textbook analysis has just been finished. In line with our expectations, we found more than 95% of the visualizations to be instructional. We further classified these as being purely symbolic, iconic or mixed (Fig. 1). On the basis of these findings, the visual model comprehension test was developed. The first version included 76 items on three scales (chemistry, engineering, general) and underwent pre-piloting with a sample of 60 high-school graduates. Based on Rasch and reliability analyses, 15 items per scale were chosen for the final instrument. This instrument is validated in a pilot study, which is currently taking place. An estimated overall sample of 280 university students will be tested three times during the course of their first two semesters. In addition to visual model comprehension, we will assess cognitive abilities (KFT-12), spatial abilities (Paper Folding Test), mathematical abilities (own test), epistemological beliefs, cognitive and metacognitive strategies (Opfermann, 2008) as well as other learner characteristics. Furthermore, students' achievement in chemistry andengineering will be assessed by means of standardized achievement tests.

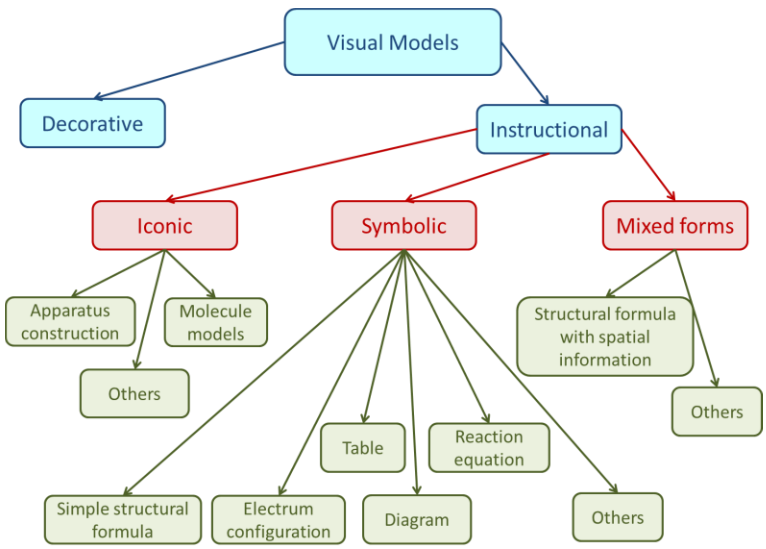

Figure 1. Classification of visual models in chemistry.

ISSUES TO BE DISCUSSED AT THE ESERA SUMMER SCHOOL

The first point of measurement time of the pilot study has just been finished. The second and third point of time will have taken place during spring and early summer, so that the summer school will provide an ideal place to discuss the results of the pilot study and gain valuable insights from experts as well as other PhD students regarding the modification of the instruments and the design of the main study. In particular, I would be happy to discuss our concept of visual model comprehension in chemistry and the question, how a test can validly and reliably assess it. Furthermore, I would appreciate the opportunity to discuss different ways of data analysis and the question of how to deal with missing data. Finally, I am interested in other opinions regarding the question, which other individual learner characteristics might relate to visual model comprehension and study success and should thus not be missed in the main study.

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MATHEMATIZATION IN CHEMISTRY QUESTIONS

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CURRENT SITUATION

All over the world, it can be noticed that the dropout rate in bachelor programs is relatively high with about 54 % in the US, about 46 % in Sweden and about 33 % in Germany (OECD, 2008). To reduce these percentages one needs to know the facts causing them which may differ according to the subjects. Hence, we are going to focus on the situation of chemistry students in Germany, who are particularly affected: The German dropout rate in undergraduate chemistry programs is at about 43 % (Heublein et al., 2012). Influencing factors are the grade point average of the student's high school diploma, his/her prior knowledge, and particular study conditions. Furthermore, it should be taken into account if the person is studying in his/her first choice program (Freyer, 2013). However, the variance can only be explained to a small extent.

Tests during the introductory phase of the study program seem to be particularly difficult for chemistry students as two-thirds of the students fail with an average percentage of correct answers below 50 %. In contrast, the high school diploma average is considerably better: only 12 to 17 % of high school students fail in chemistry and the achieved average percentage of scores is at about 65 to 70 % (QUA-LiS NRW, 2014). Due to this discrepancy we have analyzed the final exam questions in North Rhine-Westphalia (2009-2014) as well as exam questions from first year general chemistry class (first semester tests; 2012-2014). This comparison shows that the percentage of attainable points in calculation questions in high school diploma tests is at approximately 8 to 12 %, whereas it is at about 55 % and more in first years general chemistry tests. In addition, interviews with first year students confirmed that mathematization is a particularly huge problem because, according to them, there is much more math needed at university and many different formulas have to be memorized.

THEORETICAL BACKGROUND

Mathematics is a meta-science for chemists which they use to communicate (Pospiech, 2007). On the one hand it acts as a tool (symbols, characters and terms) and on the other hand it is a structuring device (Trump et al., 2014). However, high school teachers deplore the deterrent effect of mathematization (Parchmann & Schanze, 2013). When students are obliged to use mathematical skills in chemistry lessons, they often lose interest (Schmidt, Bell & Wainwright, 1975). According to latest studies mathematics is a rather popular subject so that this disinterest needs to be traced back to other causes (Pant et al., 2013). Problems of mathematization in chemistry have rarely been studied. For example, Höner (1996) has shown that embedding arithmetic problems in chemical contexts results in a significantly reduced probability of solving. There are also indicators that not the arithmetic operation itself but the lack of comprehension of parameters or chemical contexts leads to failure (Kienast, 1995; Schmidt, 1992a; Schmidt, 1990; Schmidt 1992b).

In physics, Rebello et al. (2007) have found out that using mathematical skills in a physical context is more difficult than in a math context because problems are mathematically less structured. Some studies also suggest that doing the math in physics is not just calculating within a context: differences in meaning between letters and variables as well as the use of sundry variables pose problems (Pospiech, 2013; Redish, 2006). Bagno (2008) has been able to identify two kinds of problems related to formula comprehension: students cannot describe precisely all components of a formula and they do not know the conditions under which the formula may be used.

RESEARCH PROJECT

Within this project we want to make a contribution to this research field with a cross-sectional study. The aim of the study is to identify preconditions for successfully working with chemical calculations. The hypothesis is that mathematical skills and formula knowledge are preconditions for solving chemical calculations. However, mathematical skills and formula knowledge alone do not suffice to solve chemical calculations. To test this hypothesis, first year students shall work on different kinds of questions. Based on typical chemical calculations in general chemistry five question types have been developed:

- Formula question 1: Do the students know the formula?
- Formula question 2: Can the students explain single components of the formula?
- Formula question 3: Can the students identify the needed formula from the question?
- Mathematical calculation: Can the students do the math?
- Chemical calculation: Can the students do the math in a chemical context?

All students are supposed to solve every question type for every problem. By this means we want to identify the students' difficulties and possible patterns of success. Pilot study has taken place in April 2015 while the main study will be conducted in 2016.

SELECTED RESULTS

We have run a pilot study with 73 undergraduate chemistry students aiming to become high school teachers in Germany. The tests have been held at the beginning of the second term, after all students have had general chemistry classes their first term.

The main results have led to two problematic fields. The first one is choosing the correct formula for solving the chemical calculation. Choosing the correct formula is significantly more difficult than just knowing the formula or just doing the chemical math ($F(1.378,97.643)=8.553$; $p= .000$). This means that 22 % of the students are not able to identify the needed formula, whereas they can answer the question once the formula is given. In addition, identifying the correct formula correlates significantly with the ability to explain the individual elements of the formula ($r = .544$, $p = .000$).

The second field deals with using mathematical skills in chemical contexts. Comparing the results of chemical and mathematical calculations shows that mathematical calculations have been solved significantly more often than the corresponding chemical calculations ($t(71)=6.198$; $d_{Cohen}=.75$). Thus we can assume that 30 % of the students have not been able to solve the chemical calculation, even though they had been able to solve the corresponding mathematical one.

PILOT STUDY CONCLUSIONS

The pilot study confirms that formula knowledge and mathematical skills do not suffice to solve chemical calculations. Formula comprehension only explains partially the difficulties in applying the formula knowledge and mathematical skills, thus the investigation of qualitative content comprehension needs to be complemented.

Based on the results, we have developed a scheme describing the preconditions for solving chemical calculations. The scheme includes three different levels with the first describing the preconditions for solving chemical calculations: knowledge of formula, mathematical skills and qualitative comprehension. The second level includes the application of these skills. The students have to use their formula knowledge and qualitative comprehension to choose the correct formula as well as they have to combine mathematical skills and qualitative comprehension to be able to do the math in a chemical context. The third level contains the solution of the chemical calculation. At this point the students need to use their ability to choose the correct formula and use the mathematical skills in a chemical context in a logic sequence.

We want to scrutinize this scheme in the main study, in which all freshmen in undergraduate chemistry studies at one university shall participate (N ≈ 280).

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HOW DO CHEMISTRY TEACHERS IMPLEMENT INQUIRY-BASED LEARNING IN THEIR CLASSES?

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OUTLINE OF THE FOCUS OF THE STUDY

The study aims to observe and analyse inquiry-based learning[2] (IBL) in chemistry classes at Austrian secondary schools in order to show benefits as well as challenges Austrian chemistry teachers are faced with when implementing IBL. We want use the results of the study to design continuing professional development courses, which should support teachers to strengthen the benefits and to cope with the challenges when they implement IBL.

In 2000 and 2004, the new Austrian chemistry curricula (BMBF, 2000, 2004) became effective. In these curricula, inquiry skills (National Research Council, 2000) are explicitly mentioned and therefore, teaching methods which enable students to develop such skills have become more important. IBL is an approach, which offers the opportunity to combine the development of inquiry skills with the learning of scientific content (Abrams, Southerland & Evans, 2008). Furthermore, it involves students in their own learning process and allows the teachers to adapt the tasks to the specific needs of their diverse students (Abels & Puddu, 2014).

A major problem with regard to IBL is the ambiguity about what it should be like (Abrams et al., 2008). All cooperating teachers participated in the teacher professional development programme 'TEMI' (Teaching Enquiry with Mysteries Incorporated[3]) and also in a follow-up professional development course. The 5E-instructional model (Bybee et al., 2006), the different levels of IBL (Blanchard et al., 2010; Colburn, 2000), and the three instructional goals of inquiry in the classroom (Abrams et al., 2008) provided the theoretical basis for IBL in both professional development courses. For this reason, the observations and analysis will be focused on the application of these theoretical foundations in implementing IBL on the one hand and, on the other hand, the teachers' acting during planning, implementing and reflecting of IBL-units will be investigated.

In the USA, the implementation and efficacy of IBL have been investigated in many studies, in Austria however, we effectively have no knowledge about IBL in real classroom situations. The data from questionnaires of TEMI show that the teachers have an inadequate concept of IBL and its aims and would need more support in planning and implementing IBL in their own classes, even after the workshops. To meet these demands as well as possible we have to do investigations at two levels: we need detailed information about the teachers' beliefs regarding IBL (definition, aims, levels, etc.) and we need to know how Austrian chemistry teachers implement IBL (structures of the units, materials, student-teacher interaction, etc.) in their own classes.

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[2] also enquiry-based learning (British spelling)

[3] project funded by the European Commission, Grant Agreement No. 321403

A SHORT REVIEW OF RELEVANT LITERATURE

To learn sciences by reflecting on problems and solving them has been claimed since the beginning of the 20th century (Dewey, 1910). Schwab and Brandwein (1962) argued that students must be confronted with assumptions in science education in order to be prepared to contemporary and future challenges. They described how IBL could find its way into the classrooms and emphasised the importance of well-qualified teachers, which should act as facilitators during the processes of inquiring and learning. In 1981, Welch et al. found out that the position of IBL in American schools differed dramatically from the expected one. Obstacles mentioned to the implementation of IBL were the difficult time management, the lack of materials, too little support, etc.

By publishing the 'National Science Education Standards' (NSES) (National Research Council, 1996) and the 'Next Generation Science Standards' (NGSS) (NGSS Lead States, 2013) the focus of science education moved away from teaching only scientific content towards acquiring skills and, in the following, to the learning and applying of 'science practices'. These skills and practices are closely related to IBL and are not only mentioned in the American Standards but also in the Austrian chemistry curricula (BMBF, 2000, 2004).

During this transition phase Colburn (Colburn, 2000) and Abrams et al. (2008) attend to the definition of the term 'inquiry-based learning' and complained about the ambiguity of it. Abrams et al. pointed out the impossibility of providing a single definition because of the complexity of the matter. They suggested moreover pursuing three instructional goals of IBL: "learning about inquiry", "learning to inquire", and "constructing learner's scientific knowledge". Depending on the aims IBL can be split into four different levels: the higher the level, the more responsibility the students have for the inquiry process.

The Biological Sciences Curriculum Study (BSCS) developed a model, the 5E-instructional model, which structures IBL not by its complexity but by its different phases. This model fosters the implementation of IBL and allows the teacher to design the learning units at different levels, as mentioned above. Bybee et al. (2006) considered the 5E-instructional model as appropriate for a conceptual change in both students' thinking and teachers' acting. Additionally, Coulson (2002) found that the effectiveness of the 5E-instructional model is significantly proportionate to the extent of conformity to the original designed one.

To familiarise teachers with the application of the 5E-instructional model and IBL in general, it is important to push the professional development of the teachers. Papers on this are written by Brand and Moore (2011) and Van der Valk and De Jong (2009) among others.

RESEARCH QUESTIONS

Well prepared and useful implemented, IBL enables students to acquire knowledge by themselves and develop inquiry skills and science practices up to the competence of problem solving (Hmelo-Silver, Duncan & Chinn, 2007). For this reason, it is important to support teachers so that IBL can be implemented in chemistry classes as successfully as possible. My preliminary research questions are the following:

- 1. Which beliefs do Austrian chemistry teachers have about IBL?
- 2. How do Austrian chemistry teachers implement IBL in their classes, with particular consideration given to the Explore- and Explain-phase of the 5E-instructional model and the transition between them?
- 3. Which are the challenges teachers face when implementing IBL in their classes and how do they deal with them?

OUTLINE OF THE RESEARCH DESIGN AND METHODS

The study is conducted in cooperation with chemistry teachers at secondary schools in Vienna (Austria). Based on the teachers' prior experiences from the TEMI-project and a follow-up professional development course, the planning, implementation and reflection of three IBL units per teacher are investigated. In case studies (Yin, 2009) patterns of the observed teachers in implementing IBL should be characterized and analysed over time and, moreover, the cases should be contrasted with each other. In further consequence, the findings should be connected with the literature and a professional development program should be designed.

The data for analysis and interpretation (will) come from the following research instruments: audio recording of a group discussion (N=5; to get to know detailed information of the teachers' beliefs about IBL) and of interviews (planning and reflection on the IBL-units; student-interviews to validate the teachers' estimation) (Przyborski, 2004) and video recording of classroom observation (implementation of IBL and applying the 5E-instructional model). Additionally, teaching materials and other artefacts (instruction sheets, worksheets, photos of the blackboard, schoolbooks, etc.) (Cohen, Manion & Morrison, 2011) as well as data from questionnaires previous to and in course of the TEMI-project can be used.

The group discussion is analysed by a qualitative content analysis following Mayring (Mayring, 2010). To stay as near as possible to the present data, inductive category development is applied to abstract and summarise the statements in the group discussion. Accordingly, the findings are compared with those from the questionnaires previous to the TEMI-project (answers of 257 Austrian science teachers) and relevant literature (Anderson, 2002; Wallace & Kang, 2004) to validate the process of generalization. Results will be available at the Summer School.

It has not been decided yet with which method the qualitative data from the classroom observation should be analysed; anyway, a methodological triangulation (observation, interviews, and artefacts) will be used. Currently, the documentary method (Bohnsack, 2013) or Grounded Theory (Charmaz, 2006) seems appropriate and must be weighed up against each other.

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THE RELATIONSHIP BETWEEN PRIOR KNOWLEDGE, AIM ORIENTATION AND COURSE ACHIEVEMENT IN THE UNDERGRADUATE CHEMISTRY LAB

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FOCUS OF THE STUDY

Laboratory courses are a fundamental component in undergraduate chemistry training (Reid & Shah, 2007). However, for a long time already criticism from the literature has been questioning their effectiveness and has been pointing at shortcomings in attaining learning objectives (e.g., Hawkes, 2004). In addition, such courses are very expensive in terms of material and personnel (e.g., van den Berg, 2013). These problems become particularly relevant in the light of constantly high dropout rates for undergraduates in chemistry at German universities (Heublein, Richter, Schmelzer & Sommer, 2014). In the end a lot of resources are spent on unsuccessful students. It can be assumed that at least some of these dropouts result from low achievement in laboratory courses caused by both individual and structural factors. Hence, this project seeks to assess such factors that influence laboratory-supported learning. An assessment of predictors for laboratory course achievement could explain under which conditions chemistry undergraduates become high achievers in their laboratory courses. From that, measures could be derived which improve the input-output balance of this teaching method. Higher success in introductory laboratory courses, in turn, might contribute to the general reduction of chemistry dropouts.

THEORETICAL FRAMEWORK

Laboratory courses for general chemistry are designed in a similar way across universities (Meester & Maskill, 1995a) and are accompanied by a lecture covering basic chemical concepts. Most of the time the relationship between them can be described as 'coordinated', meaning that other than teaching related topics in both at about the same time they are two completely independent courses (Abraham et al., 1997). With a scheduled average of about 160 hours for practical work per term (Meester & Maskill, 1995b) first-year chemistry undergraduates allocate a lot of time for preparing for and experimenting in the laboratory. In reality, though, students are not as prepared as expected and do not begin reading through the experiments until right before or even in the middle of a lab session. Accordingly they are unstructured during laboratory activities and produce lab reports that are often in need of improvement (Rollnick, Zwane, Staskun, Lotz & Green, 2001). This is due to the fact that they learn the content while already required to apply this knowledge in the lab. In addition, as laboratory novices they are overburdened by the huge input of new information about safety and handling of material, leaving only little cognitive resources for the underlying theory of the experiment at hand (Bennett & O`Neale, 1998). Therefore undergraduates in the laboratory can have difficulties with practical work resulting from two different types of prior knowledge deficits: first, content knowledge deficits and second, lab skills deficits, i.e., lack of experience in handling and manipulating materials and apparatus. Underachieving students would need sufficient time in advance in order to fill in these knowledge gaps. However, when their time frame is restricted because they opt for or are forced to attend a lab course during the term, they might be endangered to perform badly or even fail the course. Therefore the interplay between low prior knowledge (either content knowledge or lab skills) as an individual factor and the curricular position of the laboratory course as structural factor can have an impact on course achievement.

While the literature shows that laboratory courses are very similar with regard to their positioning and volume, this is not the case with intended aims and objectives. Up to date several attempts have been made to categorize the immense number of competencies and skills laboratory courses are supposed to foster and relate them to different types of labs (e.g., Kirschner & Meester, 1988). This definitiveness of intended aims and objectives does not mirror reality, though. In fact, the instructional design of laboratory courses seems to lack any intentions at all, which becomes evident in the absence of explicitly stated goals in lab manuals, for instance (Meester & Maskill, 1995a). Students have to guess what they are intended to learn and often anticipate and perceive other objectives instead (Wilkinson & Ward, 1998). The most prominent example from the literature of that is that instead of linking practical experiences to theoretical knowledge (e.g., van den Berg, 2013), undergraduate students engaging in laboratory activities tend to find the proposed lab results only and follow “cookbook” instructions without any deeper thought (Domin, 1999). A revised model on the effectiveness of laboratory work, based on the works of Abrahams and Millar (2008) and Bussey, Orgill and Crippen (2013), describes the mutual influence of intended learning objectives of lecturers, perceived learning of students and how they both behave and act in the laboratory (see fig. 1).

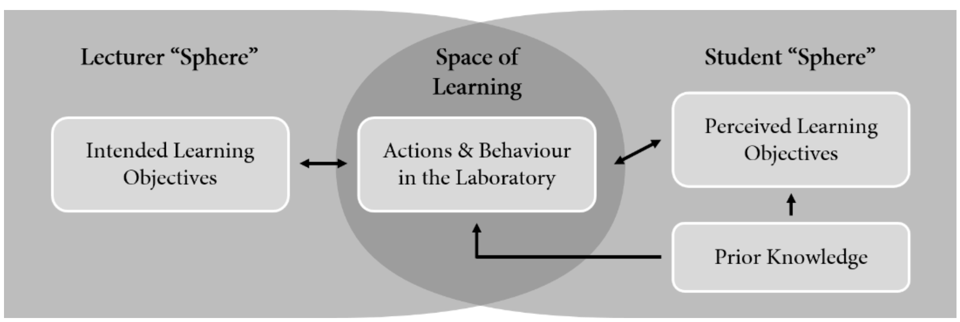

Figure 1: Model on the effectiveness of laboratory work (based on Abrahams & Millar, 2008; Bussey, Orgill & Crippen, 2013)

When the fit between intended and perceived objectives is low, the actions and behaviour of students in the lab cannot be predicted anymore and they might learn something different than intended. In the worst case, their level of prior knowledge is too low to identify any objectives at all and fail to see the purpose of what they are doing. In consequence, they cannot meet the expectations. Hence, the fit between intended learning objectives of lecturers (structural factor) and perceived learning objectives of students (individual factor) can also have an impact on course success.

RESEARCH QUESTIONS

The systematic investigation of prior knowledge, aim orientation and course achievement aims at answering two research questions:

- Q_1: Does the interaction between prior knowledge and the curricular position of a laboratory course in general chemistry have an impact on course achievement?
- Q_2: In how far does the fit between intended learning objectives of lecturers and perceived learning of students have an impact on course achievement?

RESEARCH DESIGN AND METHODS

The pilot study focuses on quality control of the test instruments and gathering of data for test instrument optimization. The sample consists of first-year chemistry undergraduates in teacher training at the University of Duisburg-Essen ($N \approx 80$) who take a mandatory laboratory course in general chemistry. Students at this university have the option to either attend a weekly course during the term or a daily course for two consecutive weeks at the end of the term. For answering the first research question, the degree of course success of the two groups ($n \approx 40$ each) will be compared. Passing of course, lab report grades and accuracy of experimental results have been selected as main constituents of course success. Two paper-pencil tests on content knowledge and lab skills will be administered to assess the different facets of prior knowledge. The lab skills test is accompanied by a practical test with five stations, where student performance will be videotaped and coded in order to account for skills that can only be observed during experimentation. Data on cognitive abilities and reported time load as control variables will also be gathered. Following the methodology of other studies (e.g., Kirschner, Meester, Middelbeek & Hermans, 1993; Wilkinson & Ward, 1998) a questionnaire with rating scales and open ended questions has been compiled for the assessment of learning objectives. Lecturers and students fill out the instrument successively throughout the laboratory course online. It lists specific learning objectives whose relevance to the according experiments has to be rated and ranked. For answering the second research question a fit measure will be determined from the obtained data and compared with course achievement.

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PRIMARY EDUCATION PUPILS' SCIENTIFIC LITERACY DEVELOPMENT WITH A FOCUS ON CHEMISTRY

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THE FOCUS OF THE STUDY

The dissertation research project investigates the effect of experiment-based science education on grade 5 pupils' problem-solving skills. There are several reasons to pay attention to this issue. It relates to the Czech pupils' results in the international assessments PISA (Program for International Student Assessment) and TIMSS (Trends in Mathematical and Science Study). Czech pupils overall achieve above-average results especially in tasks aimed at reproducing knowledge, but they fail in solving tasks focused on reasoning and application of scientific findings (Hejný et al., 2011, 2013; Mandíková & Houfková, 2012; Mandíková & Palečková, 2011; Palečková, 2007). The dissertation project also presents an opportunity to help create conditions for the development of pupils' scientific literacy (see *Gramotnosti ve vzdělávání*, 2010). Last but not least, pupils' ability to identify and solve a problem is fundamental for experimentally-oriented activities as an essential part of science education (cp. Beneš et al., 2015).

A SHORT REVIEW OF A RELEVANT LITERATURE

The important fact for the dissertation project is that research shows neutral to negative pupils' attitude towards science, namely chemistry (Rusek, 2013; Škoda, 2003; Švandová & Kubiatko, 2012) and its low popularity also (e.g Dopita et al., 2008). The late introduction of the natural (chemical) processes in education may contribute to these results (e.g. Höffer & Svoboda, 2005; Janoušková et al., 2014; Ormerod & Duckworth, 1975; Ünal & Aral, 2014). Silver and Rushton (2008) demonstrate that the earlier inclusion of science-based issues in education has a positive influence on this situation. The research among (future) primary teachers was conducted under the influence of the ideas mentioned above. Czech elementary school teachers show a lack of understanding to the essence of scientific literacy. This fact complicates creation of conditions for the primary pupils' scientific literacy development (Metelková et al., 2015).

Ünal and Aral's work (2014), which dealt with the effectivity of experimentally-oriented lessons on six-year-olds children's ability to solve problems, was the main inspiration for my dissertation research. Their results proved that experimental science-oriented activities support the development of children's skills to solve problems. The project builds on this work in order to establish the validity of the results for fifth grade pupils.

A CLEAR STATEMENT OF A RESEARCH QUESTIONS AND AN OUTLINE OF THE RESEARCH DESIGN AND METHODS

The research is based on the quasi-experimental (Campbel & Stanley, 1966) design. Research is led by the following research question:

- *What is the effect of the inclusion of experimental activities in education on grade 5 pupils' attitudes towards science topics and their ability to solve problems?*

Based on the questions, the following hypotheses were formulated for the research:

- *H_1: The integration of experimental activities in education is positively reflected in grade 5 pupils' attitudes towards science topics.*
- *H_2: The integration of experimental activities in education positively affects grade 5 pupils' ability to solve the problem of experimental tasks.*

The research follows the standard pre-test, post-test and a retention-test structure. The pre-test covers the beginning of the school year, the post-test the end of the school year and the retention test is taken in the beginning of the next school year.

The sampling

At the beginning of the research identification of comparable elementary schools will be carried out. Subsequently, the teachers who will teach in the following year in the fifth grade will be contacted. Six teachers will call to participate in research at the end of selection.

Experimental activities in the science lessons will be incorporated in two of the six selected classes. These classes will be experimental. The other four classes will be control for the research. The lessons in experimental classes with science topic will be supported by the laboratory equipment kit called The Secret of the Nature (Tajemství přírody) in these classes. Semi-structured interview with the teachers, who will incorporate the kit into their lessons, will be made. These interviews will be focused on the effectivity of the kit's implementation.

The research tools

Existing standardized research tools will be used for teachers' selection either for mapping pupils' attitudes towards science topics. The aim of the selection of the research participants is to obtain a comparable sample of teachers. The research tools (see below) will be submitted to their pupils to fill in after that.

- **Teachers:**
    - Attitudes towards science topics – The Dimensions of Attitude toward Science (DAS) (van Aalderen-Smeets & Walma van der Molen, 2013);
    - Personally formulated objective of science education in primary education (open questions).
- **Pupils:**
    - Attitudes towards science topics – "pre-Goblin questionnaire" (Silver & Rushton, 2008) (pre-test, post-test);
    - Problem solving skills – released problematic tasks with experimental themes of TIMSS (choice of tasks will be based on the consensus of two researchers from the team) (pre-test, post-test, retention test either).

The English and the Dutch version of the DAS Instrument have been validated only. By this time the DAS Instrument has been translated to Czech and pilot tested. Items of the DAS Instrument was translated to Czech and back-translated to English to validate the translated version (Brislin, 1986) For the pilot testing the teachers from the schools randomly chosen from the official list of the schools have been addressed. The schools from each region of the Czech Republic have been included. The validation of the "pre-Goblin questionnaire" is the next step of the dissertation project. The expected sample for the validation is 380 pupils approximately.

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SESSION D: EDUCATIONAL TECHNOLOGY

VIDEO HOOKS IN THE SCIENCE CLASSROOM

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INTRODUCTION

Coffman (2003, p. 2) asks, "Wouldn't it be great if our students came to class prepared – not just having read the assignment, but mentally prepared as well – alert and ready to debate, challenge, interact, and contribute?". The author advocates that students should anticipate a teaching strategy that provokes these attributes and enthuses them into an active state of learning from the lesson introduction. Considering this remit, the project examines the impact of video hooks on secondary science (11 – 15 years) students. A hook, is an instructional technique used to augment the constructs of attention (Lemov, 2010), interest (Jewett Jr, 2013) and engagement (McCrory, 2011). Theoretical positions state that hooks are a short introductory moment that puts the material out in front (Marinchech, 2013). Once the pupil is engaged, the hook has done its job. This is reiterated by Lemov (2010) who states that for a hook to be successful, it has to be short and it has to be posed at the start of a lesson.

In 2012, the School of Education at NUI Galway created a serious of video hooks for students based on the Irish science syllabus. The physics video hooks are the focus of the applicant's doctoral research and are examined through a multi-site intervention from three thematic perspectives; pedagogical usage, impact on the student body and design in a naturalistic context. The research has been carried out through a Design-Based Research (DBR) paradigm as developed by Brown (1992) and Collins (1992). The focus of this research is to investigate the use of novel, video based physics hooks and how they can be both designed and incorporated into second level classrooms to augment the constructs of attention, interest and engagement among the student body, while also developing the hook, from both practical and theoretical orientations.

LITERATURE REVIEW

The rationale for the development of hook research in science is multifaceted. However, there are two major justifications. The first is the dearth of research into hooks, their design, impact and integration into education at all levels. The second justification is the continued decline in student numbers in physics across western societies with associated literacy and economic implications. Both concepts will be explored presently.

The idea of 'hooking' students at the start of class is not new. Historical instructional models from the 1900's explore the notion of eliciting student attention from the start of instruction (Herbart, 1901). Hook-like pedagogies continued to appear throughout various developments in instructional models (Dewey, 1933) and in 5E inquiry based learning strategies (Bybee, 2009). However, hook type pedagogies are rarely subject to research agendas, barring Keller's (1987) ARCS model which gives limited instructional advice given to practitioners in terms of hooking strategies. Implicit within multiple theories of academic achievement, learning and motivation is the assumption that the student will pay attention.

Attention is a necessary precursor to cognitive processing. Motivational theories such as the Expectancy value theory and Goal orientation theory are widely advocated, however, they do not explain how instruction and tasks initially grab a learner's attention (Anderman, Noar, Zimmerman, & Donohew, 2004). Hence, this research will explore and develop video artefacts and instructional techniques to develop hook theory.

In terms of the numbers in science, international research indicates that as a student progresses through adolescence, they become less interested in science and physics (Darby, 2005). It is thought that this lack of interest is due to teaching being dominated by conduit metaphor and transmissive pedagogies (Osborne, Simon, & Collins, 2003). Contemporary science instruction is seen to lack variety and is often perceived to be less engaging than other subjects (Hampden-Thompson & Bennett, 2013). Osborne et al. (2003, p. 1074) states "It is somewhat surprising that so little work has been done in the context of science classrooms to identify what are the nature and style of teaching and activities that engage students". Therefore, new pedagogical approaches are warranted to make physics more interesting and engaging for the student.

Based on such sentiments, deficient/scant research in this specific pedagogical area, declining interest in the physical sciences and the response from literature in terms of science instruction and the reasons identified above, this research project has created, and is now assessing the impact of a suite of physics video hooks, constructed with theoretically informed pedagogical and design sensitivities. The video hooks can be found at www.sciencehooks.scoilnet.ie/physics.

RESEARCH QUESTIONS

The research addresses a primary research question which can be broken down into subsidiary questions. The primary research question is: How can physics video hooks be implemented and designed to enhance student attention, interest and engagement in physics? The supporting question which helps answer the primary question has two parts: (a) Does teaching with video hooks have the potential to target junior science student's attention, interest and engagement in physics lessons? And (b), if so: what are the integral components of physics video hooks from both a technological and pedagogical design perspective that shape the development of student attention, interest and engagement? With these questions, the thesis endeavours to delineate the characteristics of successful video hook design and utilisation in naturalistic contexts.

RESEARCH DESIGN AND METHODS

Set within a DBR framework, the methodology employs an iterative qualitative approach. Design cycle one (pilot), which took the form of a classroom based intervention, was deployed with a purposive sample of two pre-service science teachers and has been completed. The participants were asked to conduct one physics video hook intervention each with the stipulation that the hooks had to be used at the start of their respective lessons as per theory (Lemov, 2010). Interviews were conducted with the participants upon completion of the intervention along with researcher observations and reflections. As is procedure with DBR, changes were implemented towards the next design cycle.

During design cycle two, ten secondary science teacher participants from across Ireland were recruited for the study using a purposive sampling frame. Teachers were asked to use a minimum of three video hooks during three separate science classes inside a four-month period. Classroom observations were conducted by the primary researcher when the third hook intervention took place. Interviews were conducted with teachers upon completion of the project. The mainstreaming phase will inform iterative changes in the final capstone phase. The capstone phase is yet to take place, but is based upon the same intervention methods. Interviews were audio recorded and transcribed. The analysis employed a theoretical coding framework. First cycle coding was conducted by hand. Second cycle coding was conducted in NVivo 10 and used pattern and theoretical coding. Classroom observations and reflections followed the same protocol.

PRELIMINARY FINDINGS – DESIGN CYCLE 1

Significantly, design cycle one indicated that the practical application of hook theory, that is, using the hook at the start of the lesson, was ineffective with little impact on the student body. This highlighted that a pedagogical structure was required to situate the content of the video to have the desired hooking impact upon students for the following phase.

PRELIMINARY FINDINGS – DESIGN CYCLE 2

The main changes made to design cycle two based upon the former phase is that teachers were allowed to develop their own pedagogical strategy to use in association with the video. Teachers were also allowed develop this pedagogy over three interventions. With such changes, the hook had a recognisable impact upon the learning ecology in terms of attention, interest and engagement. The overall reaction can be characterised by the triggering and maintenance phases of Situational Interest (SI) (Hidi & Renninger, 2006; Mitchell, 1993). The triggering phase encompassed the two constructs of attention and emotional engagement.

The initial reaction to the video was one of disbelief. Students' first reactions were "wow", "cool", "yes" and more commonly "What?". It is positioned that these "What?" moments represent a positive emotional engagement with the content (McCrory, 2011). The emotion being displayed was interest, more specifically a triggered interest that encompassed increased attention (Linnenbrink-Garcia et al., 2010) both during and post the video hook. From this data, the EASI model (Figure 1) for video hooks was developed. It is characterised by SI at its core, however, its triggered foundation is built upon emotional engagement and attention.

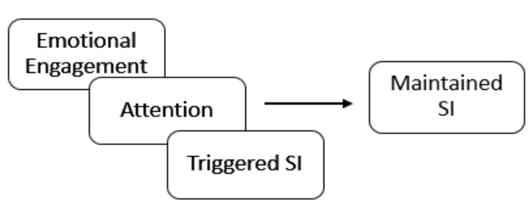

Figure 1: EASI model for video hooks.

This model will be examined in final design cycle which will assess students directly with group interviews and qualitative surveys.

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TEACHER-LEARNER-SIMULATION INTERACTION IN PRIMARY-LEVEL SCIENCE INSTRUCTION

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OUTLINES OF MY RESEARCH

Interactive simulations are a cognitively challenging environment for learners. The need for guidance during learning activities with simulations is seen as crucial for the successful implementation of simulations into science classrooms. The research on guidance has focused on how the guidance can be embedded into the simulation itself and not on the role of the teacher in the learning process. These two sources for guidance interact with one another in the classroom and thus guidance can be distributed differently between different sources. In order for the guidance to be most effective, this distribution should take into account the optimal features of all sources.

These research gaps, teachers' guidance in lessons where simulations are used and the distribution of guidance between the simulation and the teacher are the topics of my research. The impact of my research would be on giving simulation producers information on the interplay between different sources of guidance and possibly affecting in- and pre-service teacher training on how to use talk when teaching science with simulations.

LITERATURE REVIEW

Computer simulations used in science education can be defined as "computer programs that mimic the behavior of a real system" (de Jong & Lazonder, 2014). One of the most popular databases for simulations is run by the PhET-project in University of Colorado, Boulder (2016). Simulations have a positive effect on conceptual learning and both attitudes and motivation related to learning science when they are to replace traditional lectures or enhance them (Rutten, van Joolingen, & van der Veen, 2012). Research on learning with simulations has concentrated on individual views of learning and has not taken into account the role of the teacher and other pedagogical factors (Rutten et al., 2012) even though the support given by the teacher is seen as critical for the successful integration of simulations into science classrooms (Hennessy, Deaney, & Ruthven, 2006; Smetana & Bell, 2012).

Research on inquiry-based learning has raised the issue that unguided inquiry-based learning activities are cognitively too challenging for the learners and thus ineffective (Kirschner, Sweller, & Clark, 2006). These issues can be even greater with simulations which require the learners to have the necessary metacognitive skills to use to the highly interactive simulation environment (Hegarty, 2004). Zacharia et al. (2015) synthesized research results regarding different forms of guidance during different phases of computer-based inquiry-learning with simulations. They show that research has focused on the guidance provided by study materials or the simulation itself and not on the role the teachers in guiding the learners.

Even though research had focused on guidance for inquiry-based learning provided by the simulation, guidance could also be provided by the teacher. The question of what is the optimal instructional support provided by teachers when using simulations is still unanswered (Rutten et al., 2012) especially in the primary level (Smetana & Bell, 2012). Key factors of successful guidance are the same no matter who or what provides it; van de Pol, Volman and Beishuizen (2010; 2012) list the same three characteristics (i.e. adaptation to the learner, fading out and support for self-regulated learning) for guidance in teacher-learner interaction as de Jong and Lazonder (2014) list for guidance provided by the software in inquiry learning. Puntambekar and Kolodner (2005) use the term *distributed scaffolding* to describe instructional designs that include guidance by multiple sources e.g. the software and teacher. The distributed scaffolding can have three different patterns (Tabak, 2004). First pattern is that of *differentiated scaffolds* where the each of the learners' different needs is addressed by a specific form of guidance. The second pattern is that of *redundant scaffolds* where multiple forms of guidance target the same need but they are enacted at different points of time. The third and final pattern is that of *synergistic scaffolds* where multiple forms of guidance co-occur and interact with each other.

RESEARCH QUESTIONS

1) How do pre-service primary teachers' use talk to guide learners in different parts of inquiry-based lessons where simulations are used?
2) How are the guidance provided by teachers and the simulations distributed?

RESEARCH DESIGN AND METHODS

The data for answering the research questions comes from an intervention study where pre-service primary teachers (n = 40) were trained in teaching science with simulations. The choice to collect data from pre-service teachers stems from the fact that this way the number of participating teachers is higher. The lessons taught by the pre-service teachers form the data for my study. The pre-service teachers planned and taught the lessons for learners from grades 3 to 6 as groups of five with each of them being in charge of two to four learners. Four different simulations were used in the lessons which each were videotaped by two cameras. The simulation activities were recorded by using screen capture software. All in all, there are about 17 hours of video data.

For RQ 1, the analysis is based on the phases of inquiry-based learning: *orientation, conceptualization, investigation, conclusion* and *discussion* (Pedaste et al., 2015) and different types of guidance that can be offered in these phases: *process constraints, performance dashboard, prompts, heuristics* and *scaffolds* (de Jong & Lazonder, 2014). Existing research, as synthesized by Zacharia et al. (2015) has looked at how these types of guidance when provided by simulation or other external resource affect learning in different phases of discovery-based learning. I will analyze the lesson videos for what kinds of guiding actions by the teachers correspond to the different types of guidance and in which phases of the discovery-based lessons do they use which types of guidance. This will add a new perspective to the current literature on guidance related to learning and teaching with simulations.

For RQ 2 I will at first analyze how one of the simulations called *Balancing Act* provides guidance for the learners when they are experimenting with the simulation. I will also analyze how the teachers provide guidance during the experimentations with that particular simulation. The framework for guidance by de Jong and Lazonder (2014) is used to categorize guidance provided by both sources. The three categories for distributed scaffolding by Tabak (2004) are used to categorize the distribution of guidance.

PRELIMINARY FINDINGS

For RQ 1, through analyzing teacher talk during the lessons, it seems that pre-service teachers' guidance by talk can be conceptualized using the same categories for guidance as de Jong and Lazonder (2014) have done for guidance provided by the simulations. The analysis is just ready for the investigation phase of the *Balancing Act* simulation. I have been able to discern different guiding actions that correspond with the same form of guidance e.g. the teachers use prompts to prompt the learners for both answers and actions. This adds another layer of categorization for the guidance provided by the teacher.

For RQ 2, I have analyzed the guidance provided by the *Balancing Act* simulation and found that it offers process constraints, performance dashboards, prompts and direct presentation of information as forms of guidance. The teachers provide guidance for the learners during their activities with the *Guiding Act* simulation in all of the six forms of guidance by de Jong and Lazonder (2014). The analysis for the distribution of the scaffolding is still underway, but examples of all three types of distribution of guidance can be found in the data. For example when teachers paraphrase (form of guidance: prompt) an assignment given by the simulation (form of guidance: prompt), these two forms of guidance are redundant towards each other.

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DO DYNAMIC VISUALIZATIONS OF THRESHOLD CONCEPTS AFFECT UNDERSTANDING OF EVOLUTION?

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OUTLINE OF THE STUDY

Since learning in life science has special demands depending on the content at hand, there is a need for methods and tools helping teachers and learners to deal with the content. There has even been proposed a group of important concepts, threshold concepts, thought to be vital for understanding in biology. Many of these are linked to abstract or non-perceptual content, an area where visualizations for learning could be of use. My proposal aims to contribute to research on design principles for learning with dynamic visualizations. To address this, I plan to conduct studies on upper-secondary and higher education student's comprehension of content on biological evolution when working with visualizations targeting threshold concepts.

REVIEW OF THE LITERATURE

A lot of scientific content is abstract and/or non-perceptual in nature (e.g. fast or slow processes, complex, random, small scale (e.g. submicroscopic) etc.) (Treagust & Tsui, 2013). Traditionally, scientists have used instruments to overcome such limitations, e.g. microscopes or telescopes together with our imagination that allow us to build models and ultimately theories of natures inner workings. In education, this abstract and non-perceptual content could present challenges for learners and teachers (Niebert & Gropengiesser, 2015). According to the theory of conceptual change, to learn something new we draw upon our available cognitive resources, pre-knowledge and new sensory information (Strike & Posner, 1982). If we lack direct sensory experience of the object or process referred to by a concept, this might further complicate learning. Like scientists use instrument to overcome the limits of our senses, education use tools to make abstract or non-perceptual content perceptual in order to overcome the challenges (Phillips, Norris, & Macnab, 2010), e.g. models are visualized or verbalized (e.g. through use of metaphor and analogy (Lakoff & Johnson, 1980)). Hence it is not surprising that visualizations have been suggested to transform science education (McElhaney et al., 2015). Indeed, students and the public have access to increasingly powerful visual-ization tools (e.g. laptops and tablets). This means that there is great potential for bringing scientific content in diverse ways to learners, but given the mixed effects of learning with dynamic visualizations, more research on what works is needed (McElhaney et al., 2015). A good example of important but difficult scientific content that has public interest and is important in formal education is evolution (Futuyma, 1995). Research has found evolution to be difficult, even for learners in higher education (Smith, 2010) and there is a range of documented alternative conceptions (Gregory, 2009). Studies on learners' conceptions of evolution have often focused on a number of central, often called "key concepts" (e.g. variation, inheritance, differential survival) (Nehm & Reilly, 2007), but there are indications that other, more abstract concepts not necessarily specific to evolution, could be vital for understanding. These are time scales (Catley & Novick, 2009), probability and randomness (Garvin-Doxas & Klymkowsky, 2008; Mead & Scott, 2010) and spatial scales (Kalinowski, Leonard, & Andrews, 2010). These concepts are suggested to be so called threshold concepts (Meyer & Land, 2003) in biology, potentially vital for develop expert thinking in biology (Ross et al., 2010). In conclusion, abstract concepts such as threshold concepts, which also lie beyond our directly experienced world, could be one of the factors underlying difficulties to develop correct conceptions about evolution. Since visualizations have the potential to make abstract and non-perceptual content concrete (Kozma, Chin, Russell, & Marx, 2000), an interesting hypothesis would be that such visualizations also could help learners understand evolution better.

RESEARCH QUESTIONS

The overarching aim of my PhD Study is to contribute to design principles for dynamic visualizations aimed at communicating important abstract and/or non-perceptual aspects of complex phenomena in life sciences to learners. It is framed within a research project on threshold concepts and evolution. Here I have chosen to focus on questions I am currently working with:

1. How do different features of dynamic visualizations purporting to convey the role of randomness and probability affect upper secondary / higher education student's understanding of evolution?
2. How do different interaction modes in dynamic visualizations of evolution affect upper secondary / higher education student's perception of temporal and spatial scales and their significance for evolution?

OUTLINE OF RESEARCH DESIGN AND METHODS

To explore the research questions I plan to use a mixed methods design (Robson, 2011). Many studies on learning with computers use quantitative methods such as pre- and post-test designs (Müller, Sedley, & Ferrall-Nunge, 2014) to measure change in learners conceptions as a result of the application. Such test items for on learners conceptions on evolution are available from the literature e.g. Anderson, Fisher, & Norman (2002); Nehm & Reilly (2007). Together with colleagues we are also currently developing test items for the threshold concepts. The pre- and post-tests on threshold and evolutionary concepts could be used to detect any changes in conceptions when learners use the visualization. To describe any change occurring, data providing information on how the learners use the visualization as well as what happens during usage, log data and screen recordings can be used (Müller et al., 2014; Schönborn, Bivall, & Tibell, 2011). Video recordings can also be used as a complementing source of data to track critical events in learning. To capture any learning qualitatively, case studies from think-aloud sessions (Russell & Chi, 2014) and semi-structured interviews could be used (Kvale, Brinkmann, & Torhell, 2009). Qualitative data will be analysed deductively by coding of threshold and key concepts. The hope is that combining analysis of the different data sources will make it possible to get a rich description of any change in learners conceptions related to the visualization. To address ecological validity, I think about collecting data in classroom settings in upper secondary and higher education. To address reliability of results for visualization design, more precisely controlled experimental research might be needed as well, e.g. using a laboratory experiments (Gergle & Tan, 2014). In laboratory settings, internal validity can be achieved at the risk of lowering external validity (Gergle & Tan, 2014). To address this, I plan to recruit participants of the same age group and school type for laboratory experiments. In addition, evaluation of similarity of results achieved in the laboratory setting with classroom studies can inform about the validity of the results obtained (Gergle & Tan, 2014).

PRELIMINARY FINDINGS

The role of thresholds in conceptual understanding of evolution

We have performed an initial study on the correlation between threshold concepts and evolution knowledge (Göransson, Orraryd, & Tibell, 2015)). The results showed a correlation between threshold concept understanding and the scores on evolution explanations. Also, it provided valuable knowledge on the design of test instruments for evaluating conceptions on evolution. This study is still in the phase of analysis.

Characterization of online dynamic visualizations

We have also performed an explorative study characterizing online dynamic visualizations on evolution (Bohlin, Göransson & Tibell, 2014). From the study we conclude that many of the visualizations does not explicitly address the threshold concepts. In the next phase we plan for a semiotic analysis of how the different concepts are expressed to screen for promising visual designs. This study is being submitted.

Interaction design

We have also designed an application for experiments on interaction design, EvoSketch. The application is intended to convey the threshold concepts: random variation and probabilistic selection over time. So far we have conducted a pilot study (Göransson, Stenlund, & Tibell, 2015). A design for a full-scale study is outlined above.

Taken together, the potential implications of the proposed research are principles for visualization design that could enhance evolution education. Potentially, this can lead to more efficient ways of communicating scientific content and principles, in turn leading to better understanding of e.g. evolution among students or the public.

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SESSION G: CULTURAL, SOCIAL, AND GENDER ISSUES

MULTILINGUAL SCIENCE CLASSROOMS

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MULTILINGUAL SCIENCE CLASSROOMS

The Swedish National Agency for Education (2010) finds that newly arrived students are not often given the opportunity to relate linguistic expressions in their first and second languages to each other, which impedes language development in both languages. Hajer and Meestringa (2014) also note the risk that the teachers at schools where the majority of students have a first language other than Swedish tend to lower their expectations of their students, which leads to the science teaching being adapted to the students' linguistic abilities in the second language. Subject-specific language in natural science is particularly problematic. However, the later years of research in science education indicate that a linguistic movement between everyday use of language and a more scientific use of language promotes students' learning in science subjects (Olander, 2010). The question is how to create the same opportunities for newly arrived students, and what happens if these students are able to use both of their language resources in learning.

RELEVANT LITERATURE

In order to become involved in various discourses and participate in different cultural contexts, people develop skills and acquire tools, the most extensive of which is language (Engeström & Middleton, 1998; Säljö, 2010; Wells, 1999). Lemke (1990) argues that language cannot be understood as a tool for information unless it represents a prerequisite for all the meaning-making processes between people. Several learning and language development theories assume that the content and the language are intimately interwoven and that learning takes place through interaction in social contexts (Engeström & Middleton, 1998; Säljö, 2010; Wells, 1999). Therefore, an important conclusion in relation to the educational context is that the language and context are inextricably linked, and that the subject and language constitute one another and cannot be developed separately.

Language is an ongoing process depending on societally constructions (Canagarajah, 2007). In this view, language is a construction of social forces and emotions in a context, and cannot be translated immediately in a new context. Language is acculturated. García and Wei (2014) argue that language and culture are interrelated, which means that new practices constitute new languages and new cultures from the various "originals". They wrote: "for us translanguaging refers to *new* language practice that make visible the complexity of language exchanges among people with different histories, and releases histories and understandings that had been buried within fixed language identities constrained by nation-states" (p. 21). Many studies show how multilingual students use translanguaging in order to learn and understand their world (Creese & Martin, 2003; García & Wei, 2014). In translanguaging practices, multilingual students use all of their languages in a dynamic and functionally integrated manner to organize and mediate processes in understanding, speaking, literacy, and learning (Lewis, Jones, & Baker, 2012). The *translanguaging space* (Wei, 2011) is associated with the vision of *third space* (Soja, 1996), which is the hybridity theory that recognizes the complexity of people's everyday spaces and multiple resources to make sense of the world (Bhabha, 1994).

Dewey (1902) stresses the importance of a conscious and explicit instruction based on interaction between the child's everyday experiences of the world (an everyday discourse) and the more scientific description of the world (a school-related discourse). Dewey also asserted that the school-related discourse is often characteristic of an impersonal world, specialized subjects and science abstract principles, and thought patterns. *Systemic functional linguistics* (SFL) (Halliday & Matthiessen, 2004; Holmberg & Karlsson, 2006) is an approach to linguistics that considers language as a social semiotic system and the concept of a *register* suggests that all use of language can be linked to a specific situation. Many studies in science education reveal that students' modification of language in their movement between different discourses, benefiting the learning of science (Olander, 2010). Students develop a *hybrid language* (Bakhtin, 1981), a language between an everyday use of language, and a more scientific use of language (Brown & Spang, 2008; Gomez, 2007; Lemke, 1990). The study uses the concept of *discursive mobility* (Nygård Larsson, 2011) to analyze students' ability to move linguistically between and within different discourses.

WHAT THE STUDY WILL TRY TO ANSWER

The purpose of this study is to explore the ways in which multilingual students use translanguaging in primary school, and how the findings can serve as a resource for newly arrived students' science learning. The first part of the study analyzed whether and how switching between languages and different modes of expression constitutes a resource when it comes to developing a deeper understanding for the topic, and the related subject-specific language. The study investigates how students are able to use both their first and second languages in communicative science situations as a resource for learning, and how this option affects students' discursive mobility.

METHOD

The study is ethnographic and was conducted with students at a multicultural primary school located on the outskirts of a large Swedish town. The data collection started in November 2012 and followed the students until May 2015. The students' conversations were observed and the focus was how the multilingual students use their linguistic resources when they create understanding for science together with their classmates. In an attempt to create a language development instruction, the teacher used a genre pedagogical approach (Rose & Martin, 2012). The Arabic-speaking teacher participated in teaching with tutoring about half of the observed lessons. The study followed the science lessons for one week every month using four video cameras and five voice recorders, and the collected material comprised many hours of student conferences and teaching sequences. The analytical work is based on a sociocultural theoretical framework. In this method, the perceived language development and learning are intimately interwoven and the development largely takes place through interaction in social contexts. Individuals and groups gradually acquire the knowledge and the language that constitutes the discourses, which can then be used for communicative purposes (Engeström & Middleton, 1998;

Jakobsson, 2012; Säljö, 2010; Wells, 1999). The translanguaging epistemological conceives language relationships in creativity and dynamic terms (García & Wei, 2014). The participants' different semiotic resources become part of an integrated resource for all meaning making processes. By analyzing these processes in detail, it becomes possible to understand how the students in this study are able to use translanguaging as a resource in their science learning.

RESULTS SO FAR

The first part of this study reveals that multilingual students use translanguaging in the form of code-switching as resource in science instruction contexts (Karlsson, Nygård Larsson & Jakobsson, in press). Most of the code-switching situations were used in order to increase understanding of the natural science subject content. The analysis also indicates that the students' *discursive mobility* increased when they use both their first and second languages. This, in turn, led to an increased ability for the students to contextualize the abstract science subject content to their own everyday experiences. In everyday discourse, the students more often use their first language; for example, "*sends power*" and "*goes out*". However, when the students use more subject-specific words, such as "*carbon dioxide*" and "*oxygen*" they more often use their second language. This means that the newly arrived students and other multilingual students not only use translanguaging by code-switching between different modes of expressions and different registers, but they also code-switch between their first and second languages in science learning. There are two forms of code-switching in these students' *linguistic loops* between the discourses. In this way, the ability to use code-switching extends the students' communicative spectrum. This shows how a *translanguaging practice* (García & Wei, 2014) enables multilingual students to link abstract subject content to their own experiences, which empowers the students to contextualize the subject and creates preconditions for deeper understanding.

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WHITE BRITISH WORKING-CLASS EXCLUSION FROM SCIENCE: USING BOURDIEU'S CONCEPTS OF CAPITAL, HABITUS AND FIELD TO EXPLORE WHY THE WHITE BRITISH WORKING-CLASS ARE UNDERREPRESENTED IN SCIENCE

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STUDY OUTLINE

Studies have found that there is an enduring public perception of scientists as white, male and middle class (McKinley, 2005; Watts, 2006; Royal Society, 2014). It is unsurprising, then, that research suggests middle-class students are more likely to self-identify with science while working-class students may enjoy science but not aspire to pursue studies in this area, often lacking the knowledge of how to successfully convert any previous enthusiasm for these subjects (Archer et al., 2012). According to Kintrea et al.'s 2011 study of disadvantaged communities, participants from this group were the least likely to have high educational and professional aspirations. In this, and their generally low levels of academic attainment, they are a subversion of typical notions of Whiteness: privilege, power and dominance (Gillborn, 2005). Such discourses have resulted in their positioning as the 'other' (Reay et al., 2007) and led to a perception of the 'problem' white working-class. Social class continues to be a contentious issue in the United Kingdom, and this research aims to explore the reasons why class may contribute towards unequal representation in the fields of science.

In this study I will use a cultural approach to class based on theorist Pierre Bourdieu's concepts of capital, habitus and field. I will investigate the cultural resources drawn on by white working-class students when engaging in science and how this intersects with both their career expectations and the field of science education. Through this I intend to identify white working-class family 'science capital', both capital with use value and capital with exchange value. Using a framework based on field and habitus, I will explore white British working-class students' views of subject choices, of science in particular; what shapes them, and the role of gender/race/social class in shaping these views and related-aspirations.

LITERATURE REVIEW

White British working-class children, in particular boys, are amongst those social groups who consistently perform less well than the average student in national tests (Social Mobility & Child Poverty Commission, 2013). Reports to investigate this trend (e.g. Education Select Committee, 2014; DfE, 2014), suggest aspirations are a significant barrier to achievement for this social group, although there is also a suggestion that the obstacle is not low aspirations per se but rather a lack of knowledge concerning how these aspirations can be realised (Kintrea et al. 2011). Archer et al.'s large mixed methods study of family science aspirations found participants in general expressed high aspirations but not in science, and that those students who did think science was 'for them' were more likely to be middle-class (Archer et al., 2012). These findings mirror the patterns of those represented within the elite levels of science, technology, engineering and mathematics (STEM) professions (Sutton Trust, 2009) and in recent years explains calls to improve the diversity of this sector for reasons of equity and economic strength (Royal Society, 2014).

Pierre Bourdieu (1977, 1984, 1990) asserted that the reproduction of class inequalities is a product of the interplay between *habitus* (an individual's dispositions), *forms of capital* (economic, social and cultural resources) and *field* (context). Drawing on Bourdieu's conceptual framework, Archer et al. (2012) propose that habitus interacts with science-related social and cultural capital to determine how probable it is that an individual will pursue science-related qualifications and careers. Their findings suggest that middle-class families are most likely to hold science capital with symbolic value that they are able to exchange for better schools, higher-status qualifications e.g. triple science and access to science courses in prestigious universities. However, the white, working-class participants in the present sample who were very enthusiastic about science came from families with very little science-related capital to be used in the same way.

Using data collected jointly for the doctoral studentship and the 'ASPIRES 2' project, this study investigates the interplay of habitus and capital with the field of science education. It seeks to understand how this interplay can shape/ influence a student's aspirations in science, potentially contributing to understanding of the lack of representation of white working-class students in post-16 science and science professions.

RESEARCH AIMS

1. Map both the science and career aspirations of white, British, working-class students aged 10-16
2. Using Bourdieu's concept of field and habitus, explore white, British, working-class students' views of subject choices, of science in particular; what shapes them and the role of gender/race/social class in shaping these views and related-aspirations
3.
    A. Identify/measure white, British, working-class family 'science capital', both capital with use value and capital with exchange value
    B. Explore which forms of cultural capital white, British, working-class students tend to draw upon in their school subjects and how this intersects with both their chosen field of education and their career expectations
4. Identify the implications for policy and practice

METHODOLOGY

This research forms part of the larger longitudinal study, the King's College London ASPIRES/ASPIRES 2 project which tracks young people's career aspirations from the ages of 10 to 19. This thesis draws on contextualising data from the ASPIRES 2 surveys, which have received over 13,000 responses. The respondents are of the same cohort of the qualitative student participants (*N*=70) and my doctoral research is a case study of the white working-class participants from that sample and their parents (*N*=18). I have already undertaken semi-structured interviews with all participants while the students were in year 11 and will be conducting ethnographic work in the form of classroom observation with a number of them, followed by further semi-structured interviews in the final year of the ASPIRES project.

PRELIMINARY FINDINGS

While data collection and analysis for the doctoral study and wider ASPIRES2 study is on-going at the time of writing, the study has identified themes of home-school interactions, issues of cultural capital, restrained habitus, negative science-identity and the conspicuous and inconspicuous mechanisms operated in schools that can dissuade white working-class students from particular STEM routes.

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AFRICAN AMERICAN FEMALES' DISCOURSE USE AND IDENTITY DEVELOPMENT IN AFTER SCHOOL AND SCHOOL SCIENCE

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TOPIC

The gap in academic achievement between white students and students of color in the United States has been well documented (Darling-Hammond, 2005). The disparity in achievement exists across all subjects, including science (Calabrese Barton, 2001). In addition to differences in achievement in science classes, minority populations are also severely underrepresented in careers in science fields. In 2012, Latinos, Native Americans (including Native Hawaiians), and African Americans collectively held only 11% of all science and engineering jobs in the U.S. (NSF, 2014). Women minorities are even further underrepresented in science and engineering fields. In 2012, black women accounted for 6.6% of the adult population (18-65) in the U.S., but only earned 3% of the doctoral degrees in science and engineering fields (NSF, 2014). Additionally, women are outnumbered 2 to 1 in science and engineering jobs, with African American women only holding 2% of those jobs; by contrast, over 50% of science and engineering jobs are held by white men (NSF, 2014). Even in fields where the academic gap is narrowing, the troubling disparity in careers remains.

PROBLEM

One reason for the lack of minority females in science fields is that they simply don't see themselves as scientists, a view that is propagated through American society. Classic experiments called "Draw A Scientist Tests" (DAST) have been conducted for years and have overwhelmingly confirmed the belief that the vast majority of people, of all ages and from a variety of countries, accept a stereotypical view of a scientists as a white male who works in a lab and wears a white coat (Mead & Metraux, 1975; Chambers, 1985; Farland & Smith, 2009). In addition, science can be thought of as being a distinct culture, with it's own cultural norms and language (Aikenhead, 1996); in order to be a participating member of this culture, one must become proficient in the discourse of science. Because the culture of science is most similar to middle-class, white culture students from other cultures may see science as foreign and inaccessible (Aikenhead, 1996). These barriers to non-white, middle class students prevent students from developing a scientific identity – seeing themselves, and being recognized, as a scientist. This is true not just in the United States; researchers have seen similar marginaliztion of students from non-dominant cultures in many different locations, including South Africa (Oguyinni, 2006), New Zealand (McKinley, 2005), and Australia (Aikenhead, 2001) as well as marginalization of students from non-Western cultures (Oguyinni et.al., 1995).

KEY TERMS

For this research, Gee's (2001) description of identity will be used as an analytic lens. Gee (2004) argues that identity development is a two-fold process: an individual makes an identity bid, which is then either accepted or rejected by others. To make an identity bid, the individual uses the Discourses indicative of the given identity. In Gee's (2001) theory, Discourses encompass more than just language – any means of communication, including gestures, tone of voice, presentation, are included as Discourse.

Because research has shown the barriers to science identity development for certain populations in traditional science classrooms, a new type of space is envisioned in this research, based on Homi Bhabha's (1994) theory of third space. The third space is a nebulous space that organically emerges when different cultures interact. In this research, third spaces will be considered as times and places when the culture of science interacts with other cultures, such as students' home culture.

EDUCATIONAL CONTEXT

Traditional science classrooms as well as after school science programs are potential sites for third spaces to develop that allow for the coexistence of multiple Discourses and identities for students. In particular, spaces that provide marginalized populations such as African American females to interact with the culture of science are considered potential third spaces for African American female science identity development.

LITERATURE REVIEW

Research has shown that certain populations, particularly minorities and females, are alienated by traditional school science. For example, Brown (2004) examines the intrapersonal conflict that arises for African American students between academic and personal identities and cites this conflict as the reason for students' difficulties with assimilation into science environments. He demonstrates that students recognize that there are cultural stigmas associated with the use of science language and that there is a cost to using scientific discourse. Similarly, Yerrick and Gilbert (2011) also explore the conflict between science discourse and student or cultural discourse. They argue that a focus on standardized testing and science discourses such as argumentation misrepresent the nature of science, presenting science as a static collection of facts, which has made it difficult for students to form science identities. Moje et. al. (2001) examine competing Discourses in written science curriculum, concluding that the use of different Discourses was not scaffolded by the curriculum or the teacher, and that little attention was paid to the specialized Discourses of science. Finally, Emdin (2010) explores the relationship between hip hop and science, in particular the ways in which science alienates urban students and hip hop gives agency to those students. He argues for a need to explore the culture of marginalized students in order to know how to include them in the classroom. Other research focuses specifically on female students' experiences in science classes. For example, Brickhouse (2000) considers whether female students see themselves as the type of people who view the world scientifically and therefore want to participate in science, concluding that certain existing identities that the students had prevented development of science identities.

Other research has examined how out of school spaces are potential sites of science identity development for marginalized students. For example, Gonsalves et al. (2013) are investigating how the introduction of science themes into a community center program for female high school students impacts the way the girls think about and talk about science. They show evidence of the existence of a hybrid space representing school science and cultural knowledge and argue for the expansion of this space.

Some research has explored these same types of third (or hybrid) spaces in school science classrooms. Moje, et. al. (2004) explore how teachers and students use various knowledge bases and Discourses when using classroom texts, particularly in science. The authors demonstrate that the students in the study (all Latin@) privately access cultural resources, which could be leveraged by teachers in science classrooms; however, the students hesitate to volunteer these resources and the teachers do not explicitly illicit them. Several studies have further developed this framework, including: Calabrese Barton, et. al. (2008) who examine how female students create hybrid ways of engaging in science; Ramnarain and de Beer (2013) who examine the role of science expo projects in creating a hybrid space where students can connect science and home knowledges; Kamberelis and Wehunt (2012), who examine a different type of hybridity in science classrooms, that of discursive hybridity; and Charteris (2014), who examines how students enact hybrid discourses to create identity and agency in science classrooms.

RESEARCH DESIGN / METHODS

The specific research questions addressed in this study are:

- 1. What Discourses do middle school, African American female students use in an after school science program?
    - a. How do these Discourses impact scientific identity development?
- 2. When and how do Discourses used in after school environments to support scientific identities transfer to other environments, particularly science classrooms?
- 3. How do “official” Discourses (school, classroom, teacher) intersect with those used by middle school, African American female students to affect scientific identity development in the students?

A multiple-case study approach will be used for this research, allowing for an in-depth exploration of identity development for a specific group of middle school, African American female students. The research will take place over one school year (time), in the after school and in class settings (place). The replication logic approach described by Yin (2013) will be used to guide case selection. In this approach, an attempt will be made to select cases that predict similar results (i.e., two students who develop scientific identities through similar uses of Discourse) as well as contrasting results (i.e., students who demonstrate different uses of Discourse and would be expected to develop different identities). Using multiple cases will increase the robustness of the research (Yin, 2013) as well as providing a more complete picture of science identity development in African American females. Although it is of course not possible to investigate (or even identify) every possible Discourse or identity that students might use, it is important to examine a diverse subset to highlight the range of possibilities.

Within each case study, Gee’s (2004) methodology of critical discourse analysis, which assumes that all language is political, will be employed. The questions guiding the Discourse analysis are (adapted from p. 140-141, Gee, 2004): How is Discourse used to build relevance or significance for things (scientific knowledge) and people (African American females) in context? How is Discourse being used to enact and depict identities (i.e., African American female and scientific)? How is Discourse used to privilege or disprivilege different sign systems and ways of knowing (i.e., African American and scientific)?

PRELIMINARY FINDINGS – PILOT STUDY

A pilot study is currently being conducted to prepare for this study. The purpose of the pilot study is to inform both methodological as well as substantive decisions for the research project. The pilot study will aid in the selection of case study participants, exploring factors that would potentially identify a sensible case study participant (i.e., attendance in school, commitment to after school program, interest in science). In the second half of the pilot study, a pilot case study will be chosen to test and refine the case study protocol. Preliminary findings are expected Spring, 2016.

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SESSION H: HISTORY, PHILOSOPHY, AND SOCIOLOGY OF SCIENCE

ENHANCING PRE-SERVICE SCIENCE TEACHERS' ENTREPRENEURIAL SKILLS AND ATTITUDES IN NATURE OF SCIENCE AND SCIENCE EDUCATION

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OUTLINE OF STUDY

Nature of Science (NOS) and its importance have been studied for decades by many researchers (e.g. Erduran and Dagher, 2014; Lederman et al., 2002). Recently, social aspects of science started to gain attention, for example; perspectives from the economics of science and entrepreneurship (e.g. Allchin, 2011). Furthermore, educational institutions have been challenged to prepare industry-ready graduates due to the need to have more global and technological businesses (Hynes et al., 2011). Therefore, entrepreneurship including entrepreneurial skills became targeted skills in science education. For example, there is a reference to entrepreneurship in the new framework for junior cycle (2015) in Ireland and in the science curriculum (2015) in Turkey. I have decided to focus on the relationship between entrepreneurship including entrepreneurial skills, economics of science and NOS in science education[4]. Therefore, the main objective of this study is to (a) scrutinize the place of entrepreneurship and economics of science in the social-institutional system (SIS) of science in NOS, (b) understand the pre-service science teachers' perspectives on the inclusion of entrepreneurship and economics of science in NOS and (c) investigate methods of the use of entrepreneurship and economics of science for science classroom practice. Ultimately, I aim to contribute to the literature by developing a holistic approach on how science works as an SIS via introducing entrepreneurship and economics of science as a missing piece in the operation of science. Although science is not considered as a single entity, by science I refer to Physics, Chemistry and Biology because I conduct this research with science education students who study these three sciences.

LITERATURE REVIEW

The review of literature points to a variety of research on NOS, for example, assessment methods for NOS and the characterisation of NOS (e.g. Allchin, 2011; Erduran and Dagher, 2014; Irzik and Nola, 2011; Lederman et al., 2002). However, a substantial shortcoming between the research studies is that the social aspects of NOS including economic aspect and entrepreneurship are underdeveloped. For instance, Family Resemblance Approach (FRA) is one of the NOS approaches adapted to science education by Irzik and Nola (2011); however there was a deficiency of explicit and elaborated inclusion of social aspects involving economic traits in science. Erduran and Dagher (2014) extended the FRA to develop a more comprehensive understanding of NOS by examining science as "a social-institutional system" (SIS) as well as a cognitive and epistemic system and it is this view of NOS

[4] *Key Terms of the Study:* NOS deals with how science works. In this respect, it is characterised as a comprehensive area of research in science education incorporating perspectives based on cognitive, epistemic, social, political, scientific, and economic aspects of science education as advocated by Erduran and Dagher (2014) and Irzik & Nola (2011). Economics of science deals with understanding the impact of science on the advance of technology, the behaviour of scientists, and the efficiency and inefficiency of scientific institutions (Diamond, 2008). Entrepreneurship "is the ability to create and built something from practically nothing" (Timmons, 1989, p.1).

that is used in this research. Within the context of NOS, I conceptualise how science works as an SIS, and answer the question of what activities scientists do.

Even though the extended FRA situates the social, political and economic aspects of science for educational purposes, the theoretical ideas imported from the formal disciplines of economics of science and entrepreneurship to NOS in science education is rare. Many researchers conducted studies on the economics of science (e.g. Audretsch et al., 2002; Erduran and Mugaloglu, 2013; Diamond, 2008; Irzik, 2007; Stephan, 1996). According to Diamond (2008, p.1), "economics of science aims to understand the impact of science on the advance of technology, to explain the behaviour of scientists, and to understand the efficiency and inefficiency of scientific institutions". Some scopes of economics of science are "science and scientists in industry" (e.g. Romer, 2001; Stephan, 1996), and commodification and commercialisation of science (e.g. Erduran and Mugaloglu, 2013; Irzik, 2007). These scopes point to the relationship between science and society which is important to understand how science works as an SIS. Moreover, it is worth noting that the extended version of FRA has many overlaps with economics of science. For instance, how science works including the behaviour of scientists is highly important for both economics of science and NOS (e.g. Diamond, 2008; Erduran and Dagher, 2014). Thus, it can be inferred that economics of science is related to NOS. In the context of economics of science, I answer the question of where scientists work and how the products, services or scientific knowledge produced by the activities of scientists become available in the market[5]. This process of making the new patented product obtainable in the market is the commercialisation of science[6] and entrepreneurship is closely associated with this process.

Entrepreneurship enables the transfer of the knowledge and patents from scientific field to the market to produce services or products to satisfy the public need (Birdthistle, 2007; Hisrich and Peters, 2002; Hynes et al., 2011). This feature of the entrepreneurship is also related to economic growth. "The relevance of entrepreneurs for economic growth and of science as a source for entrepreneurial opportunities has only recently been rediscovered" (Sanders, 2007, p.339). For instance, Sanders (2007) presents a model connecting entrepreneurship research, the philosophy, economics of science and modern growth theory by taking some key insights away from each. Therefore, I can infer that entrepreneurship is related to economics of science. Likewise, as mentioned before, economics of science is related to NOS. As is seen, there is an implicit relationship between NOS and entrepreneurship. Moreover, entrepreneurship needs entrepreneurial skills. According to Timmons (1989, p.1), entrepreneurship is "the ability to create and built something from practically nothing, it is initiating, doing, achieving and building an enterprise or organisation rather than watching, analysing or describing one". To do that, entrepreneurs need entrepreneurial skills such as critical thinking, creativity and risk-taking skills (European Commission, 2012), which are also targeted skills in science education worldwide (e.g. DES 2015; Board of Education and Discipline, 2015). Furthermore, there is research on the importance of using entrepreneurship in science classes (e.g. The Entrepreneurial School Project, 2013-2014; European Commission Report, 2012). Thus, in the context of entrepreneurship, I answer the questions of how the production (e.g. patents, scientific knowledge) of scientists is transformed into

[5] Market is the place where the buyers (e.g. public, entrepreneurs) and sellers (e.g. companies, entrepreneurs) interact to trade products and services to fill the supply and demand gap.
[6] Commercialisation of science is presented as one of the scopes of economics of science in page 2.

products or services for the public need, how these products or services are transferred from scientific field to the market, and how the activities of scientists affect or are affected by society.

In light of what I have presented thus far, I propose a cycle to illustrate how science works as an SIS in the context of academic, market and industry domains and is, referred to as AMI Cycle (See Appendix-1). The AMI cycle provides a practical and visual tool which could help enhance not only the comprehensive understanding of how science works as an SIS but also students' awareness of the relevance between science and the market, and transformation of the scientific knowledge into a product and service. In short, I seek to enhance pre-service science teachers' entrepreneurial skills and understanding of economics of science in NOS and science education.

RESEARCH QUESTIONS (RQS)

- **RQ-1:** How science works as a social-institutional system?
    - **1.1.** Why does integrating entrepreneurship and economics of science into NOS and science education matter?
- **RQ-2:** What are the perspectives of pre-service science teachers on "science as a social-institutional system" in NOS and science education?
- **RQ-3:** How can pre-service science teachers' entrepreneurial skills and attitudes be enhanced in NOS and science education?
    - **3.1.** What sort of impact does using story-based-argumentation have on improving pre-service science teachers' critical thinking skills as an entrepreneurial skill?
    - **3.2.** What sort of effect does developing a concept statement have on increasing pre-service science teachers' creativity/innovation as an entrepreneurial skill?
    - **3.3.** How does solving a crisis which occurs in a concept statement develop pre-service science teachers' risk taking and problem solving skills as entrepreneurial skills?
- **RQ-4:** How is pre-service science teachers' understanding of "science as a social institutional system" affected by participating in this study?

RESEARCH DESIGN AND METHODS (See Appendix-2)

RQ-1 will be answered by the critical review of the literature. For this goal, I have been writing two papers. In the first paper, the role of entrepreneurship and economics of science on how science works as an SIS have been discussed. In the second paper, the relationship between economics of science, entrepreneurship, science and science education have been argued. For both papers, some activities have been created to show how the theoretical knowledge can be applied into classroom practice. Before starting the main research, pilot research is conducted in Turkey (n=4) and Ireland (n=3). For the main research, the data is collected from 16 participants at University of Limerick (UL). The rationale for choosing 16 participants is to keep enough students to conduct this research since there is a possibility of withdrawal of some participants from the study. RQ-2 and RQ-4 are to understand the perspectives of the participants on the topic. "Interviews enable participants to discuss their interpretations of the world in which they live, and to express how they regard situations from their own point of view" (Cohen, Manion and Morrison, 2011, p.409). Therefore, pre- and post-interviews are used to gather data to answer RQ-2 and RQ-4. Thematic analysis will be used to analyse the data as it is best suited to elucidate the participants' conceptualisation of the phenomenon under study (Boyatzis, 1998; Joffe, 2012). To answer RQ-3, four participants will work on a story-based argumentation activity where they are expected to argue two claims[7] based on a real-world science story. The rationales for choosing argumentation activity are that (a) argumentation is related to critical thinking and problem solving skills, and (b) this activity involves economics of science perspective. This activity will be analysed by an argumentation quality framework (Osborne et al., 2004) and content analysis. Secondly, participants develop a business idea related to science and write a two-page concept statement[8] of this idea in three weeks in accordance with the instructions given by the investigator. The rationales for choosing this activity are that this activity (a) is related to creativity/innovation skills, and (b) comprises an entrepreneurial perspective. Thirdly, participants do a focus group discussion to provide researcher deeper information on how participants have developed their concept statements. Fourthly, the researcher creates a crisis on the concept statements; for example, if the targeted company does not buy the product what participants will do to overcome this problem. Participants write a report on how to solve this crisis in two weeks. The rationale for choosing this activity is that this activity is related to risk taking and problem solving skills. The concept statement and the crisis management reports will be analysed by content analysis.

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[7] Claim 1: Science is a social-institutional system, Claim 2: Science is not a social-institutional system

[8] Concept statement (CS) is an overview of a new product or service proposal. CS can be seen as a foundation of a business plan.

Appendix-1

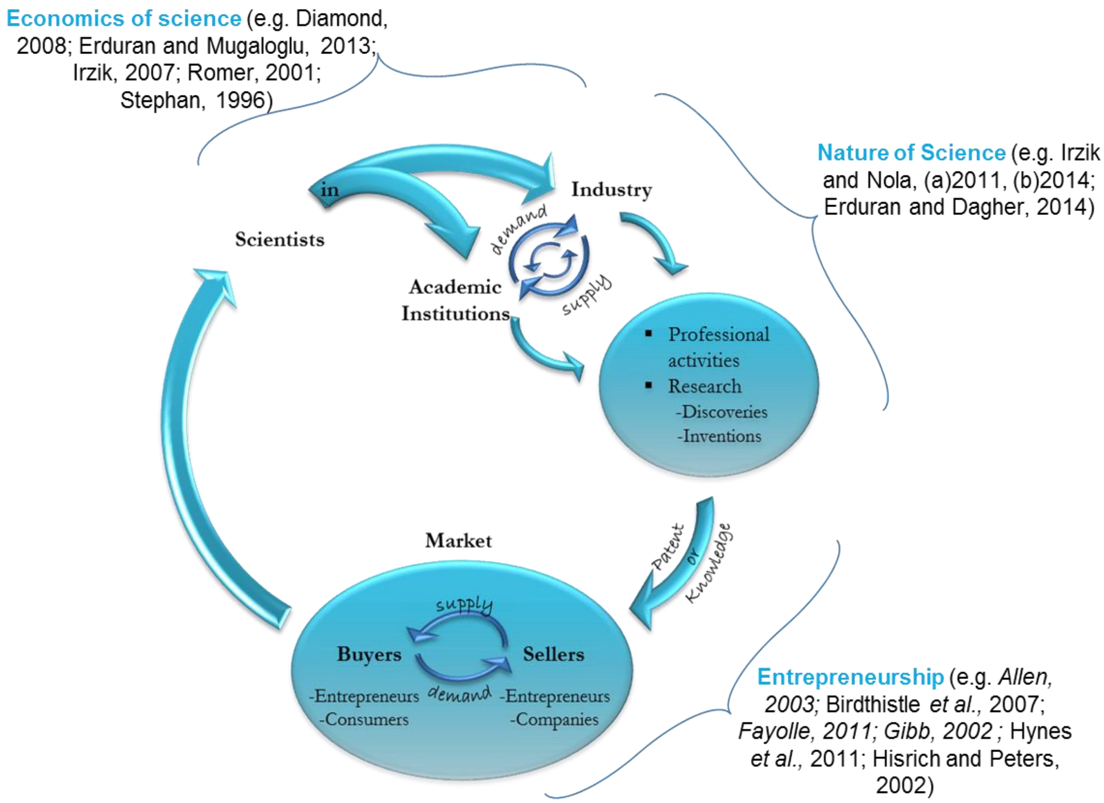

Figure 1: AMI Cycle

Appendix-2

	RQ-1	RQ-2	RQ-3	RQ-4
Sample Size	Critical review of the literature + Analytical discussion	Pilot interview *(n=7)*, Main Interview *(n=16)*	Pilot study *(n=7)*, Main study *(n=16, divided into 4 groups)*	Pilot interview *(n=7)*, Main Interview *(n=16)*
Data Collection Method		Semi-structured Interview	Argumentation, Workshops (concept statement, crisis management), Focus group discussion	Semi-structured Interview
Data Collection Tool		Audio-record (face-to-face interview)	Audio-record, Participants' written report	Audio-record (face-to-face interview)
Methods		Qualitative RM.		
Analysis		Thematic Analysis *(Braun and Clarke, 2006)*	Argumentation quality framework *(Osborne et al., 2004),* Thematic Analysis *(Braun and Clarke, 2006)*, Content Analysis	Thematic Analysis *(Braun and Clarke, 2006)*

Table 1: Research Design and Methods

INVESTIGATING AND EVALUATING OUTREACH AND PUBLIC ENGAGEMENT PROGRAMMES, TO ESTABLISH WHETHER THEY CAN IMPROVE/ENHANCE SCIENTIFIC LITERACY

Laurie Ryan

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OUTLINE OF THE FOCUS OF YOUR STUDY

This work is set in the broader context of societal challenges in current and future times. STEM research is high on the agenda of policy makers globally, particularly within Ireland and the European Union. This is reflected in strategy and funding call documents across both zones, particularly with investment into strategic applied research being prioritised in Ireland as an aid towards economic recovery (SFI 2015; OECD 2007). With STEM research so high on the agenda, the responsibility to communicate research outcomes and impacts to the public is also increasing. This work aims to evaluate how well we communicate and educate the public through STEM awareness/outreach programmes and establish whether they improve understanding of Nature of Science (NoS) and Scientific/STEM literacy among a target population, in this case among post-primary pupils and teachers. It will also look at the effect that embedding argumentation, IBSE and NoS into these programmes has on pupils understanding of science. This work will draw from socio-cultural perspectives of learning and utilise a framework (still being established) to develop a toolkit which will help both researchers and practitioners develop activities which can enhance scientific literacy through informal learning activities. The goal is to work with the main research funding body in Ireland, Science Foundation Ireland (SFI). SFI has 12 research centres across the country, all of which are required to participate in educational outreach programmes. The work will establish how STEM research is currently communicated to pupils and teachers, and whether scientific literacy is being effectively enriched through these methods. Finally the framework and toolkit which will be developed will be evaluated in order to establish whether enhanced scientific/STEM literacy for pupils and teachers has been achieved.

LITERATURE REVIEW

In recent years, scientific literacy has become an educational goal of most countries. Many educationalists (Bybee 1991; Millar & Osborne 1998) describe scientific literacy as the main purpose of science education. However, among many practitioners, curriculum developers and policy makers, there is often an assumption that if an individual knows enough Science that they will be able to apply it in life situations (Bybee and McCrae 2011). Driver, Newton and Osborne (2000) state that: *"the claim 'to know' science is a statement that one knows not only what a phenomenon is, but also how it relates to other events, why it is important and how this particular view of the world came to be. Know any of these aspects in isolation misses the point."*

The Programme for International Student Assessment (PISA) is a project of the Organisation for Economic Co-operation and Development (OECD), and in 2013 they defined scientific literacy as "the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen." (p.7).

A scientifically literate person should be able to ask and answer questions about their life and the world around them, they should also be able to critically read and evaluate science and other news articles and arguments, while having the ability to communicate adequately about political issues with scientific roots. According to PISA Assessment Framework (OECD, 2003), education for universal scientific literacy will, in addition to enriching everyone's lives, create a larger and more diverse pool of students who are able to pursue further education in scientific fields and are motivated to do so. It is acknowledged that scientific literacy can improve as a person matures in science understanding (NRC, 2004). It has been stated that one way of making science accessible to the public and providing opportunities to engage with it, is through public engagement events where scientists are in a position to interact with public audiences (Besley & Tanner, 2011). The International Council for Science (ICSU) strategic plan for 2012 – 2017 states that they want to "increase visibility and outreach, making maximum use of website and other social networking and multi-media tools" (p.10). It has been in recent years, in Ireland, the importance of science and technology in economic, social and environmental problems faced by the world today has been recognised. This is something needs the support and active engagement of the public. "An engaged public is one that understands the role of science, can judge between competing priorities and arguments, encourages young people to take STEM subjects, and feels that it has the appropriate level of engagement with, and influence upon, the researchers" (SFI, 2015).

With many conceptions and values attributed to scientific literacy one must consider which stance is appropriate. For the purposes of this study scientific literacy encompasses four key areas: conceptual (school science versus real world science, the context and narrative), Cognitive (reasoning ability, arguments and argumentation and meta-cognition), ideas-about-science (NoS, epistemology of science) and social and affective. Each of these key areas draws upon established areas of research, such as NoS, Argumentation and Inquiry-Based Science Education (IBSE), all with a significant body of literature on each theme, although the precise definition of each can be contentious.

RESEARCH QUESTIONS THE STUDY WILL TRY TO ANSWER

1. How is scientific/STEM research communicated to the specific target groups (post-primary pupils and teachers)?
2. Is the target group's scientific literacy being improved through this communication/informal engagement?
3. Is there a way to utilise informal learning of contextulised/real-world science (STEM research) to enhance target group's scientific literacy?
4. Can a framework be developed to enable more effective and meaningful engagement and communication of scientific/STEM research to the public to promote and enhance scientific literacy?

OUTLINE OF THE RESEARCH DESIGN AND METHODS;

This research undertaken for this project is diverse by its nature, with many different facets being examined and assessed. There is no “single blueprint” for planning a research study; a study must be governed by the notion of ‘fitness for purpose’ (Cohen et al. 2007, p. 78). The study will draw from socio-cultural theories, utilising a constructivist theoretical framework. The scope of this study is broad, and while general results are sought, the multifaceted nature of education research requires a deeper understanding of the complexities involved in this research study. The research questions will be honed and utilised to focus the study. Scientific/STEM literacy are becoming integral to our society as a whole. This study seeks to establish whether we improve teachers and pupils in STEM literacy through our extensive Education, Outreach and Public Engagement Programmes, using methods such as Argumentation, NoS and IBSE. In order to comprehend the situation, a variety of data from different sources would need to be gathered. The research will utilise a mixed-methods approach, which is frequently classed as the third research paradigm (Collins et al. 2006). This approach is utilised to complement different aspects of the study, and to triangulate the research. It may be thought of as the third research paradigm. This approach offers the researcher choices, both in how the study is designed, but also in what methods to use for data collection, analysis and interpretation. It is an eclectic approach, being derived from the similarities between the two approaches and the desire to overcome the weaknesses of each approach on its own (Snape and Spencer 2003).

Overall, it is envisaged that a number of instruments will need to be developed and validated, utilising appropriate techniques. All statistical analysis will be carried out using SPSS. NVivo will be utilised for coding and analysis of qualitative data. All instruments developed will be checked for validity and reliability. The research study will be broken down into different phases. Phase 1, (which is currently under way) of the research will involve conducting a comprehensive literature review of the work on STEM communication and engagement, Nature of Science, Inquiry-Based Science Education, Argumentation, Scientific Literacy and Informal and non-Formal learning.

Phase 2 of the work will use the findings from Phase 1 to develop a test instrument to evaluate whether initiatives currently in place develop scientific/STEM literacy among pupils and teachers at post-primary school.

Phase 3 will synthesise the data and literature analysis. From this a framework and toolkit will be developed. The aim of this will be to enhance the target groups’ understanding of NOS and improve their STEM literacy through their participation with STEM research groups/communicators/outreach and engagement programmes. This framework and toolkit will be developed through participatory action research with STEM outreach specialists/communicators, STEM researchers, teachers and pupils.

Phase 4 will utilise and evaluate the framework and toolkit with STEM researchers and communicators, teachers and pupils on a national level.

Through this work I will evaluate the current situation regarding the type of STEM outreach and awareness programmes available, the engagement that is taking place and the overall effectiveness in the context of understanding NOS and improving STEM literacy. I will work with these key stakeholders through participatory action research to develop a framework and toolkit, which will be informed by the findings from the previous stage of research, to enhance understanding and deeper engagement. This work will be piloted and project participants will be provided with appropriate training, which will have been developed in conjunction with the toolkit and framework. The framework, toolkit and training will be evaluated on an on-going basis and this will be the final stage of the research study.

PRELIMINARY FINDINGS (if available)

This study is in its inception, and to date a thorough literature review has been conducted. It is for this reason that the ESERA Summer School would be so beneficial. The study is still at the stage whereby ideas and reflections from the learning at the summer school could be merged with the current work, thus enhancing both the study and the researcher.

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UNDERSTANDING THE LEARNING PROCESSES IN SCIENCE MUSEUMS – A LONGITUDINAL STUDY OF ELEMENTARY SCHOOL STUDENTS

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FOCUS OF THE STUDY

Documenting the learning that occurs in science museums proves challenging because of the informal structures in which the learning takes place (Falk & Dierking, 2013). Nevertheless, such informal learning environments can potentially bridge the gap between peripheral populations and the scientific language and knowledge that are needed for public scientific discourse.

This study aims to investigate long term experiences of elementary school students in a science museum. The theoretical anchors of our research are: the contextual model of learning and the socio - cultural approach.

This study is unique because of its duration, focus and setting. First, the participants of the study will visit the museum over a period of three years. Second, it will focus on school group visits (which are less explored, unlike free choice visits and family visits). Third, the study will take place in the "Carasso Park for Science" situated in the city of Be'er Sheva. The science park was built in a region of Israel deemed 'peripheral' (geographically and socio-economically).

This study will elaborate our understanding of the long term learning processes in science museums. Since learning is a cumulative process, longitudinal studies can illuminate the learning process occurring. Such a longitudinal approach will map out the function of repeated visits. It can shed light on the ways that subsequent activities connect with and reinforce the outcomes of the activity. In addition, this study will contribute to the pedagogical aspect of assessing learning processes.

REVIEW OF THE LITERATURE

Today, science is a major part of western culture. In a globalized world, education in science, technology, engineering, and mathematics (STEM) has become a gatekeeper for participation in global productivity and wealth systems (Osborne & Dillon, 2007). Discussions about the need for members of the public to access and understand scientific information are well established. Serious scientific concerns are ubiquitous in modern life (global warming, alternative fuels, and stem cell research), and in a democratic nation, an educated population is needed to inform public policy. People learn science from a variety of sources, from a variety of places and for various reasons. The reality is that schools cannot act alone, and society must better understand and draw on the full range of science learning experiences to improve science education (National Research Council, 2009, p. 12).

Opportunities to engage with science are not accessible to everyone. Science museums, as informal learning environments, aim to achieve the goal of making science accessible to all. Public engagement with science (PES) has become an umbrella term that includes practices in informal science learning environments. These environments make substantial contributions to science education, but are not necessarily being distributed evenly among all communities (Dawson, 2014).

Museums as a phenomenon began as institutes that presented collections of cultural value to the public. Science museums have changed in the last few decades, transforming from an institute of knowledge that collects artifacts to an educational environment for the public, and a place where the visitor can construct knowledge through interactive engagement with exhibits (Tal & Morag, 2007). Science centers and museums are now important resources for learning science.

Designed informal learning environments can be used to further science education, but because research on the topic of formal environments is far more extensive than research of informal environments, the question of how precisely knowledge is acquired in such settings remains unclear (Osborne & Dillon, 2007).

RESEARCH QUESTIONS

1. What characterizes the learning process that takes place in a science museum, particularly within the context of the elementary school students' visits?
    a) What sorts of cognitive and affective interactions take place between peers during the school visits?
    b) Are there certain aspects of the science museum exhibits that have a particular impact on students' engagement and interactions during the visit? If so, what are they and what sort of impact do they have?
    c) What characterizes the interactions that take place within different types of mediation means during the visit?
2. What are the unique contributions of bringing the elementary school students on recurring visits to the science museum over a three year period?

RESEARCH DESIGN AND METHODS

The research is taking place in "Carasso Science Park". The population of this study include: A) Students in grades 4-6 - 3 classes from schools in Be'er Sheva that participate in the study over 3 years, visiting the science museum twice a year with their school, B) The students' teachers and C) Museum guides.

This study is will combine two main theoretical frameworks - Ash's discourse analysis framework (2003) and the contextual model by Falk and Dierking (2013). In addition, we will add a set of categories that emerge from the findings in our research. Our main tools for gathering data in the museum are video recorded observations (during the visit) and open ended interviews with the staff (after the visit). Within a week of the visit, we will interview each student, at the school, using semi structured interviews. Our research is a qualitative study, relying on the interpretivist (hermeneutic) epistemology that is embodied in the relativist-contextualized paradigm. This paradigm uses multiple data forms in order to describe and interpret learning in a comprehensive way. These regard factors such as visitor agendas, motivations, and socio-cultural identities as influential to the learning process.

Observation

Observations in qualitative research enable the collection of more data and assist in the process of enriching the data as well as its triangulation (Patton, 2002). This study will adopt two types of observation – 1) observation of the entire group when undergoing instruction and 2) observation of the engagement around an exhibit.

The visitor engagement framework (VEF)

This model is a visitor-based framework for assessing visitor learning experiences with exhibits in a science center setting. The framework consists of seven learning behaviors (Barriault & Pearson, 2010) that can be grouped into three categories that reflect increasing levels of engagement and depth of the learning experience (initiation, transition, and breakthrough behaviors). This study uses the framework in the exhibition halls to evaluate 9 specific exhibits.

In-depth and semi structured interviews

Interviewing aims to understand other people's experience, and the meaning they make of that experience (Patton, 2002). During this research we will interview the students, the guides and the class teachers.

The research will use both inductive and deductive qualitative analyses. Inductive analysis involves discovering patterns, themes and categories from the data itself. In deductive analysis, on the other hand, the data is analyzed according to an existing framework (Patton, 2002). In the museum, the interactions that facilitate engagement with the exhibits may emerge from the inductive data analysis (categorization), whereas the VEF model provides a deductive framework for analysis. In addition, we will use discourse analysis as well. Many studies in informal environments adopt the socio-cultural approach when analyzing results, and since discourse is an important component of this approach, discourse analysis is a common tool in studies in museums (Ash, 2003). In this study, discourse analysis will take place at several stages: a) group instruction around exhibits – discourse analysis between guide and students; b) analysis of discourse between students around exhibits. We will use the discourse analysis method, "Dialogic Unit of Analysis: Significant Events" (Ash, 2003). To ensure that the study is trustworthy, significant attention is paid to the validity and credibility of the study. We will attend to its validity by documenting all decisions making, and to its credibility by recording detailed observations and ''thick descriptions''. In addition we will use triangulate data from multiple sources for comparison (Guba, 1981).

PRELIMINARY FINDINGS

So far we have finished our data collecting of 1800 students aged 10-12 (4^{th}, 5^{th} and 6^{th} grade), in 9 exhibits in the museum (200 students in each exhibit). We have used the VEF model to analyze our observations, in order to characterize the aspects of science museum exhibits that have a particular impact on students' engagement during the visit.

Our observations revealed several characteristics that contribute to engagement with exhibits in science museum. For example, exhibits that facilitate social interaction will increase engagement, designing the exhibit like a game contributes to visitors' interaction, and using a familiar real-world phenomenon will encourage visitors to engage with the exhibit to the highest extent.

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SCIENCE IDENTITY DEVELOPMENT THROUGH SUPPLEMENTAL SCIENCE EXPERIENCES

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OUTLINE

Studies into declining participation in post-compulsory STEM (science, technology, engineering and mathematics) subjects in developed nations show students commonly choose to discontinue studying STEM subjects because they do not identify as people who do science (Archer et al., 2013; Aschbacher, Li, & Roth, 2010; Lyons & Quinn, 2010). This is concerning for governments, industry and educators as STEM related jobs show strong growth and STEM skills are known to be critical for innovation and productivity across occupations (Educational Council, 2015). Attempts to rescind declining enrolments in post compulsory STEM study have found that informal science learning out of school can support students development of science identities and engagement in science (Rahm, Lachaine, & Mathura, 2014). This supports the proposal that a more accessible and effective science education may be achieved through the collaboration of school and out-of-school learning (Stocklmayer, Rennie, & Gilbert, 2010). Schools commonly utilize out-of-school learning experiences but often do so individually and inconsistently with limited reports of outcomes available, especially concerning students' perceptions and attitude change (Bevan et al., 2010). My research aims to investigate science identity development in students whose schools regularly attend a science centre designed to link industry, university and local schools in that area.

LITERATURE REVIEW: SCIENCE IDENTITY DEVELOPMENT

Today many students think science is important and interesting but often it is not a vocation that they identify with and subsequently they do not wish to pursue it as a career (Archer et al., 2010; Aschbacher et al., 2010; Lyons & Quinn, 2010). This phenomenon is particularly prevalent amongst students from ethnic minorities, from low socio-economic backgrounds and in girls, all of whom are consistently under-represented in STEM professions (Carlone & Johnson, 2007). In order to understand why otherwise capable and interested students are turning away from STEM, researchers have developed a broader socio-cultural oriented perspective which focuses on the wider role society plays in youth identity development and vocation choice. Within this approach identity is seen as an individual construction but one which is shaped through existing social structures and power relations which can limit the identities, choices and aspirations perceived as possible (Archer, DeWitt, & Willis, 2014). From this research has emerged the concept of science capital; science related forms of Bourdieu's social and cultural capital which are huge influences on whether youths aspire to STEM careers (Archer et al., 2012). Students whose families have high levels of science capital possessed stronger science identities as they had support such for developing their interest and competence in science (Archer et al., 2012). The problem then for educators is how viable science identities can be developed in students from families who do not have extensive science capital.

Identity can be treated as a performance; gender, ethnicity and other aspects of identity are something you do and do not do through specific talk and practices in specific contexts (Archer, DeWitt, et al., 2013; Ideland & Malmberg, 2012). Recognition of a scientific identity performance by meaningful others is key to making science identities sustainable by students (Barton & Tan, 2010; Carlone & Johnson, 2007). The norms imposed within a school science classroom assign certain knowledge and behaviour to the identity performance of a 'good science student' (Tan, Barton, Kang, & O'Neill, 2013) which may exclude genuinely interested students for whom this sanctioned identity carries negative and undesirable social connotations for students (DeWitt, Archer, & Osborne, 2013). Often school institutional and cultural narratives of 'legitimate science' can exclude the wider science related interests and activities of students (Carlone, Scott, & Lowder, 2014). Providing a setting that is more inclusive of different types of scientific knowledge and ways of participating in science creates a more flexible definition of science identity which accommodates the identities and practices of students' everyday experiences (Carlone et al., 2014; DeWitt & Archer, 2015; Tan & Barton, 2010). However creating this setting is difficult to achieve in a classroom on a regular basis (Barton & Tan, 2009).

Informal science learning that occurs out of school can provide multifaceted portrayals of science within an authentic and cultural context that students can relate to (Bevan et al., 2010). However typically such experiences are unique and lack the structure and sustained time that schools are capable of, making it hard to discern long term impact or reproduce desired effects on a large scale (Stocklmayer et al., 2010). Collaborations between informal and formal school based learning of science is thus proposed as a way to take advantage of the structural and social properties of both sectors to offer students a science that is accessible, contextualized and meaningful (Bevan et al., 2010).

Meaningfully connecting the two worlds of school science and out-of-school science can enable students to bridge their school science learning and the values and activities of their families and culture. Increasing the overlap between a science identity and a students' existing identities across their family, peer group and community, makes it easier and less threatening for students to engage in science identity work (Carlone et al., 2014). Bridging the two worlds also means a successful science identity performance in one world can be carried to the other (Barton et al., 2012; Tan et al., 2013) which can support students who are hindered by classroom dynamics or who have disengaged from school (Tan & Barton, 2010). Yet despite prevalent use of formal-informal collaborations by schools there is limited reporting on the outcomes, particularly concerning students' development of a science identity (Bevan et al., 2010).

The few studies that examine science identity development in such collaborations are limited in scope, typically consisting of case studies with very few participants and often with heavily skewed populations such as of under-represented youth (Tan & Barton, 2010) or self-selecting science lovers (Todd, 2016). The type of formal-informal collaborations also vary immensely in time (both frequency and duration), activity structure and content covered, which limits the applicability of findings from individual studies. As calls increase for a joint formal-informal approach to science education it is necessary to obtain a more comprehensive picture of the impacts of formal-informal collaborations and what role they can play in developing students' science capital and science identity.

RESEARCH QUESTION

- Do out of school experiences at KIOSC affect students' development of a science identity?

RESEARCH DESIGN AND METHODS

This research will use a mixed methods design in which quantitative data collection and analysis will be supplemented by qualitative data collection and analysis (Creswell, 2013). Design of research instruments draws heavily on the big longitudinal studies of ASPIRES in the UK (Archer et al., 2012) and 'Is Science Me?' in the US (Aschbacher, Li, & Roth, 2010) which looked at student identity in science learning and aspiration formation. Also used was the Expectancy Value Theory of Achievement Motivation (Eccles, 2009) which illustrates how students' sense of identity affects their educational and career decisions (Abraham & Barker, 2015). 100 students in years 7, 8 and 9, (the first three years of secondary education in Australia) from two schools were recruited for this research. Both schools were part of a six school consortium with the Knox Innovation Opportunity Sustainability Centre (KIOSC) and students attend excursions there at least twice a year. Students will complete a questionnaire on their participation in science and some basic demographic information to establish their level of science capital and identity affiliation with science. The impact of students' experiences at KIOSC on their science identity will be explored in a series of student focus groups. Teachers and KIOSC staff will also be interviewed individually about the impact of the KIOSC experience on students.

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ANALYZING AND PROMOTING THE EXPLICIT INTEGRATION OF VALUES AND EVIDENCE IN STUDENTS' DECISIONS ABOUT DIET ELECTION: THE VEGETARIANISM DILEMMA

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OUTLINE

This doctoral research project aims to investigate how students integrate evidence and values in their argumentation and decision-making about Socio-Scientific Issues (SSI), and to develop scaffolds for promoting the explicit intertwining of values and evidence.

Research shows that evidence and values interact in students' decisions and arguments about SSI (Grace, 2008; Kolstø, 2006), as SSI include both social and scientific factors (Zeidler et al. 2005). It has been suggested that educators should give more space to student values in SSI (Bell & Lederman, 2003; Sadler & Zeidler, 2005) and foster their awareness of values and the application of value-based criteria (Kolstø, 2005).

We chose the topic of diet election (vegetarian vs omnivorous) as the SSI context for our study considering several reasons: the actual growing concerns on how to feed global population in the future (FAO, 2009), the current studies assessing the impact of diets on sustainability (Stehfest et al., 2009), the recent concerns raised regarding long-term impact of diets on health (WHO, 2015), and the shortage of studies addressing this topic in science education.

FRAMEWORK

The public's ability for decision-making and argumentation is deemed of high relevance in our actual complex technology-driven democratic societies (Aikenhead 1985; Millar and Osborne 1998; Newton et al. 1999; Zeidler et al. 2005).

The quality of decision-making in SSI has been related to many skills, such as argumentation (Zohar & Nemet, 2002) the understanding of the Nature of Science (NOS), and conceptual knowledge (Sadler, 2004). Similarly, research indicate that performance in socio-scientific argumentation is related to students' ability of evaluating evidence (Fleming, 1986; Kolstø, 2001), NOS conceptualizations (Sadler, Chambers, & Zeidler, 2004), and value-based reasoning (Fleming, 1986; Sadler & Zeidler, 2005). Acar et al. (2010) have emphasized the need of incorporating the findings of decision-making research to argumentation, highlighting the importance of three factors, (1) the awareness of heuristics (i.e. automatic and unconscious reasoning strategies); (2) taking values explicitly into account; and (3) providing a framework for assessing the evidence and tradeoffs for each alternative considered.

Value-based reasoning is essential in decision-making, as decisions are never based on knowledge alone, being values necessary for judging the desirability of different consequences or alternative decisions (Kolstø, 2005). Research shows that students decision are more value-based than knowledge-based (Acar et al., 2010; Christenson et al., 2014), but many questions regarding their degree of awareness of their value-based reasoning and the way they use it remain still unsolved (Acar et al., 2010).

Aiming at helping students evaluate alternatives by taking their values explicitly into account, Parasketa et al. (2015) used an scaffold strategy called optimization which involve three componentes: (1) transformation of raw data in a single metric, (2) adjustment for the relative importance of the criteria assigning weights depending on values, and (3) calculation of weighted scores for each solution.

Determining if these scaffolds are effective requires a method for assessing the quality and competence of SSI decision-making and argumentation. The TAP model (Toulmin, 1958), arguably the most extendend analytical framework in argumentation, has been considered insufficient for studying solutions to ill-structured problems (Voss, 2005), although several attempts have been carried out to enhance its adequacy for studying SSI arguments (Osborne, Erduran & Simon, 2004; Zohar & Nemet, 2002). Kelly et al.'s (2008) framework is useful for examining arguments that combine several reasoning lines, as it is usually the case in SSI argumentation. For the assessment of the decision-making competence, Eggert & Bögeholz (2010) developed a model aimed at evaluating the use of tradeoffs, the ability to weigh decision criteria and the ability to reflect on the structure of the decision-making process. Another tool developed for the analysis of students' productions about SSI is the SEE-SEP model (Rundgren & Rundgren, 2010), which is useful for revealing the distribution of supporting reasons through different subject areas (sociology/culture, economy, environment, science, ethics/morality, and policy) and sources (Knowledge, Values and Personal Experiences), but doesn't acount for the semantic relationships within justifications, or among evidence and values.

RESEARCH QUESTIONS

The doctoral research project addresses the following research questions:

- To what extent and how are integrated values and scientific evidence in the argumentation and the decision-making process about the diet election dilemma?
- What are the criteria and arguments that drive students' decisions about diets?
- How the scaffolding strategies carried out help expliciting students' values when dealing with decision-making about diets? Does this scaffolding influence SSI argumentation and decision-making quality?

RESEARCH DESIGN AND METHODS

A preliminary study was conducted with 74 pre-service primary teachers focusing on the first and second research questions. The methodological approach is qualitative, seeking patterns through systematic analysis (Merriam, 2009). The teaching sequence involved students in tasks about evidence evaluation, criteria for strong arguments and balanced diets. They worked in 20 groups of 3-4 students and constructed a written argument about an appropriate diet during a 90 minute session. Data collection included multiple sources, student teachers' written products (pre-test, portfolio reports, final essays) and recording of oral debates. Their written discourse was analyzed with rubrics constructed in interaction with data (Glaser & Strauss, 1967) and drawing from Kelly et al.'s (2008) analysis of lines of reasoning. Students' justifications were also coded using a modified version of the SEE-SEP model to seek for relationships among the subject areas used, the sources for their justifications and the outcome of the decision-making process.

A second data collection based on the optimization strategy as scaffolding for decision-making is planned for the next year and is currently on the design and planning stages.

PRELIMINARY FINDINGS

The group reports (N=20) showed a diversity of diet elections: 7 reports proposed an omnivorous diet (O), 10 omnivorous with reduced animal products consumption (O-) and 3 proposed a vegetarian or vegan diet (Vg). The analysis of the articulation of lines of reasoning showed that 10 reports (50%) weaved their reasoning through an explicit convergence, and only 4 (20%) presented no signs of convergence. The discourse analysis points towards a dynamic interplay between values and scientific data in building inferences and claims, as shown in Figure 1.

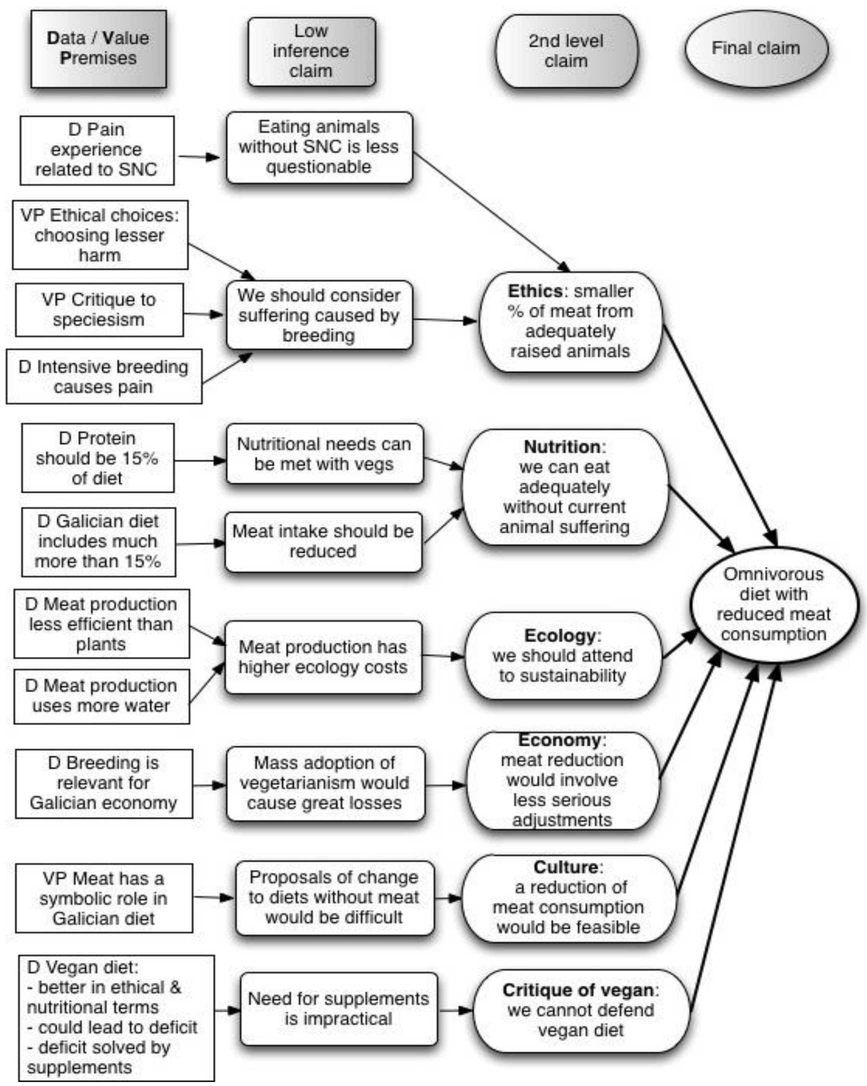

Figure 1: Convergence of reasoning lines in the argument from Group 2.2.

The SEE-SEP analysis for the sources of the 545 justifications identified show that Knowledge was the most used (54.3%), followed by Values (42%) and Experiences (4.8%). This result contrast with previous studies, which emphasized the use of past experience (Albe 2008; Patronis et al., 1999), and with other studies using the SEE-SEP framework, which found Values as the most frequent aspect (Christenson et al., 2012; Christenson et al., 2014). The predominance of Knowledge in our study could be related to the influence of the previous activities of the teaching sequence and to the availability of handouts with content information during the task.

Regarding the criteria for diet election, in the pre-test, nutrition was the most used to justify both diets, (100% for omnivorous, 92% for vegetarian); ethical reasons were used by 100% in support of vegetarian, while reasons related to ecology and sustainability were almost non-existent. In contrast, we found a diversification of criteria in the group reports: 10 (50%), considered five dimensions (ecological, ethical, nutritional, economical and cultural), and 16 reports (80%) considered 4 or more. A progression is then documented from limited and generic principles towards an enactment of more sophisticated and specific criteria.

The SEE-SEP analysis for 5 subject areas (corresponding to each one of the dimensions) show that the Science (nutrition) category was the most frequent (29.5%). Groups proposing different diets showed differences in the distribution of justifications throguh the subject areas, being Science the most used for the groups proposing O and O-, while Ethics for the groups proposing Vg. These differences point towards a relationship between different patterns of prioritization of the subject areas and the outcomes of the decision-making process.

In the full study additional research is planned for covering the use of scaffolds and for delving further into the criteria and the integration of values and evidence in students' decision-making and arguments.

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FOSTERING CONCEPTS ABOUT THE NATURE OF SCIENCE (NOS) IN INCLUSIVE CHEMISTRY CLASSES USING UNIVERSAL DESIGN FOR LEARNING (UDL) PRINCIPLES

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In 2009, the German government ratified the "Convention on Rights to Persons with Disabilities" (CRPD). Due to the ratification, inclusive instruction became crucial for the German educational system. This led to the establishment of inclusive schools in every Federal State. The Federal State Lower Saxony implemented inclusive instruction in summer 2013 posing new challenges for chemistry teachers. Correspondingly, there is little evidence about designing learning environments for German special-needs learners. Additionally, we have a lack of knowledge about learning processes in these inclusive environments.

THEORETICAL BACKGROUND

Scientific literacy is supposed to prepare all students for participating in social life. Thus, the idea of this central science education concept is close to inclusive instruction. At the same time, concepts about the the Nature of Science (NOS) play a key role for developing scientific literacy. The "nature of science education needed to prepare students for the kind of scientific literacy necessary for responsible citizenship" (Holbrook & Rannikmae, 2007, p. 1348). These concepts include "developing social values", "being able to function within the world of work" and "conceptual background or skills of learning to learn" concerning relevant knowledge and public understanding about science and technology in a changing society (Holbrook & Rannikmae, 2007, p. 1353). With regard to the students with special needs, fostering these concepts in an inclusive setting is an important and challenging goal for chemistry education. However, until now, approaches that focus on how to foster NOS concepts inclusively are rare.

However, Universal Design for Learning (UDL) provides guidelines for designing inclusive learning environments (CAST, 2011; Price, Johnson & Barnett, 2012). "UDL is an approach that seeks to address an inflexible one-size-fits-all traditional curriculum that often presents barriers to struggling learners by replacing it with universally designed curriculum or curriculum that is created with the intention of including all learners" (Brownell, Smith, Crockett & Griffin, 2012, p. 81). King-Sears et al. (2015) applied this approach in chemistry education and showed that students with disabilities in the UDL treatment received substantially higher learning gains than students with disabilities in the comparison condition.

RESEARCH QUESTIONS

Against this background, the aim of the present study is to design and evaluate a learning environment based on UDL principles to foster NOS concepts in inclusive chemistry classrooms. The PhD investigation follows four research questions that correspond to four perspectives on the project:

- **Research question 1 (conceptual perspective)**: Can UDL principles be used to design a learning environment to foster NOS concepts in inclusive chemistry classrooms?

- **Research Question 2 (explorative perspective)**: Do special needs learners have specific preconceptions about NOS?
- **Research question 3 (procedural perspective)**: How do students perceive their learning in inclusive environment that is supposed to foster NOS concepts?
- **Research question 4 (outcome perspective)**: Does a learning environment based on UDL principles lead to a more effective fostering of NOS concepts in inclusive chemistry classrooms?

METHODS

Figure 1 shows the study design.

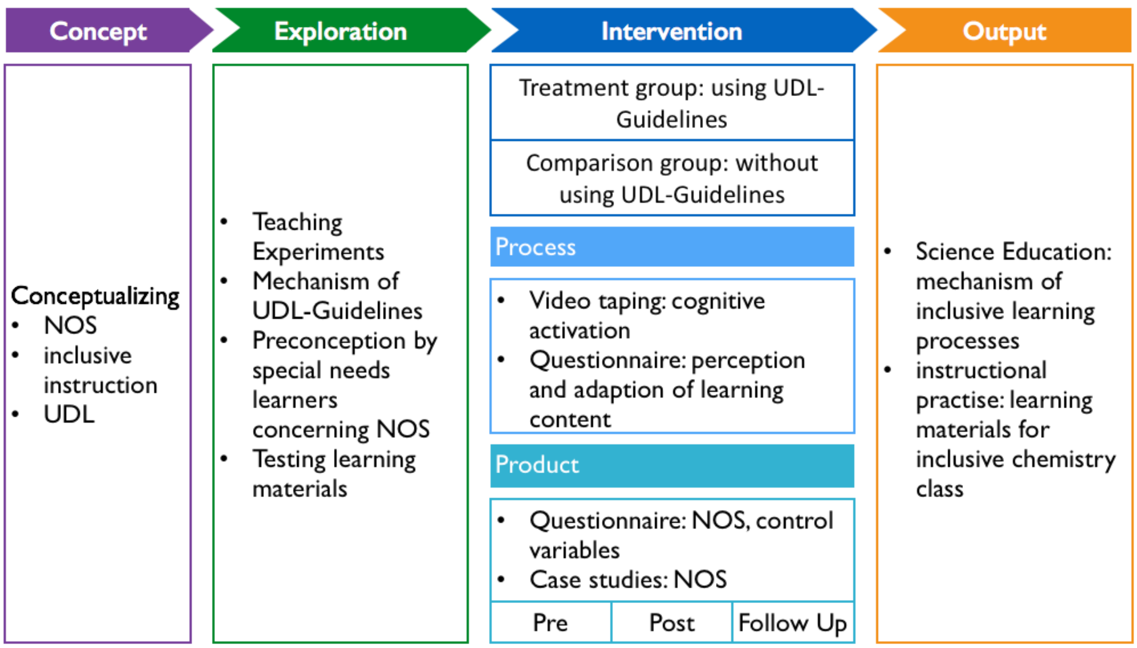

Figure 3: Study design

Conceptual perspective

The term “learning environment” intends theoretical based practice-oriented learning materials composed to an instruction. In order to design the learning environments, we refer to vast knowledge about inclusive teaching from the USA (e.g. McGinnis & Kahn, 2014; McGinnis, 2013) and the UDL principles as well as to the Conceptual-Change theory (Appleton, 1997; Clough, 2006). The learning environment is conceptualized according to Appletons conceptual change framework(1997) and “draws teachers’ attention to students’ reasons for exiting from instruction. Furthermore, it “makes explicit that the teachers’ role is to accurately assess students’ reasons for exiting and determine if and how students’ exiting is to be redirected” (Clough, 2006, p. 489).

The learning environment shall foster the NOS concepts “creativity”, “simplicity” and “purpose of science”. These concepts will be combined with the principles “Multiple Means of Representation and Engagement” (CAST, 2011).

Explorative perspective

So called “teaching experiments” including interviews will be used to answer research question 2. This allows us to investigate “students’ pre-instructional conceptions and in which way students can be guided to the science point of view. It also facilitates closely linking empirical research on teaching and learning processes with the development of instruction” (Komorek & Duit, 2004). Therefore, we will compare the NOS conceptions of students with disabilities with the conceptions of those without disabilities and those reported in the literature. We use a sample of about nine students in three groups. Pre- and post clinical interviews will measure the development of NOS concepts following Carey et al. (1989). Every group will work with the three parts of the learning environment.

The results are used to focus on the environment and its usability and accessibility as well as on the preconceptions of the students.

Procedural and outcome perspective

For answering research questing 3 and 4, the learning environments will be implemented into inclusive schools during an intervention study of 3 lessons à 90 min using a pre-post-intervention control group design. Every class will work with the above listed NOS concepts. For examination of the chosen UDL principles and their effects, treatment condition 1 contains “Multiple Means of Representation”, and treatment condition 2 contains “Multiple Means of Engagement” and treatment condition 3 contains both principles. Comparison condition 4 contains no UDL principles. Chemistry teachers will use the learning environment. For data analyses, we need about 50 students per condition.
In order to measure the perception of students’ learning in class, we will use a questionnaire about perception learning content after every lesson (Knierim, 2008). Furthermore, we use video recording to measure the level of cognitive activation to get information about the instructional quality (Baumert et al., 2010).

Finally, we want to know which effects can be found while fostering student’s NOS concepts in inclusive classrooms (research question 4) by using a NOS questionnaire on pre post and delayed post testing time (Urhahne, Kremer, & Mayer 2011). To this product perspective we add clinical interviews with randomly selected students (Carey et al 1989). This mixed method approach gains more detailed data about progression and initiated internal processes during the intervention.

OUTLOOK

In the current phase, the learning environments are designed. From April to June 2016, data from teaching experiments will be collected and analysed. The findings as well as the inclusive learning environments will be presented and discussed at ESERA summer school 2016.

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THE CONTRIBUTION OF VISUALIZATIONS TO CONSTRUCT SCIENTIFIC EXPLANATIONS ABOUT CHEMICAL REACTIONS: A STUDY WITH 8TH GRADE STUDENTS

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SUMMARY

This project has its foundations on the idea that having students involved in the construction of their own scientific explanations (SE) improves students' conceptual understanding and science reasoning. Nevertheless, empirical studies point that the construction of SE is a complex and cognitively demanding process. In that process, among others, students face difficulties in inferring underlying processes for explaining observable phenomena. From a different perspective, visualizations has been gaining recognition within the educational community for facilitating richer conceptual understanding of unobserved phenomena and its connection to observable events. In light of this it is important to understand how the construction and use of visualizations facilitates the construction of SE. Several studies have focused either on SE or visualizations, but they seldom have made an attempt to explore both issues together. In addition, these studies have mainly focused on students' SE as a product, rather than on the process of constructing SE. Considering this gap in literature, the aim of this study is to know how students' use and construction of visualizations facilitates the process of constructing SE.

REVIEW OF LITERATURE

The potentialities of engaging students in the construction of their own explanations have been highlighted for improving science knowledge construction and conceptual understanding, for making sense of natural phenomena and for fostering engagement with science classes (e.g. Barteen & Windschitl, 2011; NRC, 2012; Osborne & Patterson, 2011). Considering the perspective that students learn science by actively engaging in authentic practices, also it is argue that, as explaining natural phenomena is a primary goal of science, students should be encouraged to learn a system of interconnected ways of thinking and to develop SE of everyday natural phenomena.

Despite its potentialities constructing SE is a complex practice which requires such abilities as to use scientific ideas, observations and evidences for supporting reasoning, to infer underlying mechanisms and to establish causal relations (Braaten & Winschitl, 2011; Grotzer, 2003; Yeo & Gilbert, 2014). Empirical studies reveal that frequently students struggle with these actions and that, as a result, their SE often fail to present several important characteristics. For instance, frequently students' SE are not supported by scientific ideas or evidences (Ruiz-primo et al., 2010); they do not include casual accounts going beyond simple linear causality (Grotzer, 2003; Kang et al., 2014). In addition, students tend to simple restate or describe the information provided without giving additional insights (Talanquer, 2006) and they do not infer underlying mechanisms for making sense of observable events (Cheng & Brown, 2015; Yeo & Gilbert, 2014).

Particularly in chemistry, in which observed phenomenon involves theoretical ideas about particles that are too small to be seen, one common reason for the pointed out difficulties is the lack of students' experience in coordinating two very different levels of representation: the descriptive and functional (macroscopic level), where the phenomenon is perceived, and the explanatory (submicroscopic level) where the phenomenon is conceptualized in terms of unobservable entities and processes (Taber, 2013). Recent research has shown that visualizations support the conceptualization of these levels and its coordination, promoting students' understanding of science theoretical ideas (Prain et al., 2009; Yeo & Gilbert, 2014).

GOALS

Considering that constructing scientific explanation is cognitively demanding for students, and also the potentialities of visualizations in facilitating richer conceptual understanding of unobserved phenomena and its connection to observable events, it is important to understand how the use and construction of visualizations facilitates the construction of SE. Several studies have focused either on SE or visualizations, but they seldom have made an attempt to bring both issues together. Some of the studies, focused more the students' conceptual ideas and ability to use multiple-levels of representation, using the SE as an artefact to assess it (e.g. Chandrasegaran & Treagust 2008; Prain et al., 2009), and others focus their attention on the product obtained rather than on the process of construction an explanation (Talanquer, 2010; Kang et al., 2014).

Regarding this lack in literature, the aim of this study is to know how students' use and construction of visualizations at different levels of representation (i.e. macroscopic and submicroscopic) facilitates the process of constructing SE. In particular, specific goals of the project are: (a) to describe the visualizations used by students and how they evolved during a learning-sequence; (b) to describe the nature of students' SE and how they evolved during a learning-sequence; (c) to identify the nature of students' difficulties regarding the production and use of visualisation and how they evolved during a learning-sequence; (d) to identify the nature of students' difficulties regarding the construction of SE and how they evolved during a learning-sequence.

RESEARCH DESIGN AND METHODS

Context and participants

A learning-sequence on chemical reactions was designed, including seven inquiry-based activities about chemical reactions. All activities followed a similar structure: to plan and conduct lab-activities, to make observation and describe, to construct and use visualizations at macroscopic and submicroscopic level and to construct SE. The learning-sequence was undertaken during regular physics-chemistry lessons and it was applied for 28 consecutive lessons, with students working in groups of 3-4 elements each. A total of 108 students, from five different 8th grade physics-chemistry classes, from a Portuguese public school. Students were following the elementary physics-chemistry curriculum, which in Portugal comprehend the last three years of the third cycle of basic education, from 7th to 9th grade (12-15 years). The teacher involved in the project was a Ph.D. student in science education, and have training and practice in inquiry based science education and in the use of visualizations.

Data collection

In order to evaluate the impact of the learning-sequence on students use and construction of visualizations and SE we applied a test prior the sequence and after. In the pre-post-test, students were asked to present visualizations and SE, on four open-response questions about familiar natural phenomena related to chemistry and particulate nature of matter. The aim was to characterise and describe the nature of students' visualizations and SE and to know how they evolved.

With the aim of understanding the nature of the difficulties of the students and to appreciate how students' ability in the construction of visualization and SE have evolved all of the process was observed. The researcher during to the learning-sequence observed all lessons of the five classes (total of 140). The researcher adopted the role of "observer-as-participant" (Cohen et al., 2007), taking field notes in a form of diary, audio-recording groups' work (total of 6300 minutes) and collecting students' work (with drew visualizations and written SE).

Finally the researcher conducted focus group interviews, with the aim to described the nature of students' difficulties during the learning-sequence in construct their visualizations and SE. The researcher previously selected visualizations and SE constructed along the learning-sequence. The interviews were carried after the application of the post-test. In each of the five classes, two groups of 8-10 were conveniently chosen. Each interview toke approximately 40 minutes.

Data analysis

In order to analyze the nature students' SE, a system of analysis was constructed based on students' answers and theoretical frameworks on SE (Braaten & Winschitl, 2011; Grotzer, 2003; Salmon, 1998), and chemical education concerning the multilevels of representations (Taber, 2013; Talanquer, 2010).

In order to analyze the nature of students' visualizations, a system of analysis was construct based on students' answers and literature on visualizations (Parnafes, 2012; Prain et al., 2009) and chemical education (Taber, 2013; Talanquer, 2010; Assaraf & Orion, 2010).

The reliability of the constructed systems of analysis was ensured by the inter-rater between the researcher and the first supervisor and between the researcher and the second supervisor.

To identify the evolve of explanation and visualizations during the learning-sequence we use descriptive and inferential statistics.

Qualitative analysis is use to analyse the data collected during the learning-sequence (i.e audio-recording transcriptions and field notes) and interviews. First, the field notes are used to select key episodes from audio-recordings groups' work, looking for insights for the way students got involved in construction of visualizations and used them to constructed their SE. After, qualitative analysis are conducted using classical content analysis (Cohen et al., 2007), which involve an iterative process of data coding, describing and verification. The validity issues are ensure through data triangulation and independent researchers review of data.

PRELIMINARY FINDINGS

The present status of the study allows to foresee that students' SE and visualizations evolve from the pre to post-test condition. The results from the pre-test show that the majority of students´ SE are descriptions or associations of non-articulated information, rather than causal stories that tells how and why the phenomenon happens. Regarding the post-test, the results show that the majority of students´ SE are causal accounts that partially tell the story of how and why the observed phenomenon happens.

Considering visualizations, the pre-test results evidence that the majority of students made static representations of the phenomenon without representing the interaction and processes underneath the phenomenon. In the post-test results the majority of students' visualisations evidence dynamic representations that highlight some of the relevant interaction and processes that bring the phenomenon about.

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PUPILS' MULTIMODAL MEANING MAKING AROUND SPECIATION

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INTRODUCTION

It is often claimed that the acquisition and understanding of language is essential in biology (e.g. Ross et al., 2010). Lately *threshold concepts* (Meyer & Land, 2003, 2005; Ross et al., 2010) within several science disciplines, such as the theory of evolution, has been highlighted as essential for understanding. Threshold concepts, such as variation, probability and temporal scales, can be described as a "conceptual gateway", that leads the person into new ways of understanding. Learning science includes acquiring new concepts, in that sense it can be compared to learning a new language. But before becoming verbally proficient, young children rely in a high degree on embodied actions, prosody, and pointing to communicate (Mercer, 2007). In communication, humans often use different sign systems, or modalities, for example speech, gestures, pointing, and physical materials (Jewitt, Kress, Ogborn, & Tsatsarelis, 2001). Thought and knowledge are often carried and expressed through modalities additional to speech, and meaning that is understood as a whole can be expressed through different modalities simultaneously (Streeck, 2009). Hence, developing knowledge and understanding of scientific phenomena usually involves more than what is expressed verbally (e.g. Callinan, 2014).

Within the field of science education research, traditional data collection methods, such as written tests and interviews, are very common. This is also the case in the research studying how pupils in different ages understand evolution theory. Evolution theory is seen as a complex topic and is a well-studied field in science education research. However, there are not many studies with a particular focus on younger pupils (e.g. Berti, Toneatti, & Rosati, 2010; Evans, 2000; Samarapungavan & Wiers, 1997; Shtulman & Schulz, 2008). Previous studies have shown that children have non-evolutionary conceptions (Samarapungavan & Wiers, 1997) as well as creationist understandings (Berti et al., 2010). However, these studies do not consider that knowledge is constructed and can be expressed through several types of semiotic resources (Jewitt, 2011; Leijon & Lindstrand, 2012; Selander & Kress, 2010) additional to verbal language. These traditional methods of collecting data might give a limited picture of pupils' knowledge. We know little of the role of materials and how it might work as a semiotic resource in children's' meaning making process around evolution.

AIMS AND RESEARCH QUESTIONS

The aim of this project is to investigate how six-year-old pupils make meaning about speciation in interaction with other pupils and with access to teaching material. In addition, the aim is to look into how young pupils explain evolution, more precisely speciation, and how explanations relate to threshold concepts (Meyer & Land, 2003, 2005; Ross et al., 2010). Accordingly, the research will be guided by the following research questions:

- How do pupils in preschool class reason to explain speciation?

  - What traces of threshold concepts are visible in pupils reasoning?
- How are semiotic resources used in the process of making meaning around evolution and speciation?

RESEARCH DESIGN AND METHODOLOGICAL PERSPECTIVES

One data collection has been made with 27 six-year-old pupils in preschool class. Data consist of individual interviews, approximately 4-10 minutes each, 8 group interviews, 10-25 minutes each, and drawings. None of the pupils had had any formal education on evolutionary theory or speciation. The research follows ethical guidelines.

Data collection

Data have been collected in three steps over a period of two weeks. Throughout all the steps the pupils were being asked to answer the question: "Lions, tigers, snow leopards and jaguars are all 'big cats'. Several million years ago all big cats looked alike. How come they look so different from each other today?". Photographs of a tiger, a lion, a snow leopard and a jaguar in their natural habitats and toy figurines of the cats placed at their natural geographical location on a topographical world map, were used in all steps.

Initially the pupils drew an individual picture showing their ideas. Spontaneous interaction between the pupils was video captured. In addition, the drawings served as a tool for communication (Brooks, 2009) and as a shared point of attention (Ainsworth, Prain, & Russell, 2011) for the following individual interviews and group discussions.

In the next step, the pupils elaborated their answers in video recorded individual semi-structured interviews. Finally, the pupils collaboratively discussed the question in groups of three to four pupils. Video recordings made it possible to collect data of how gestures and other semiotic resources were used in interaction.

The second collection of data will include at least 30 pupils. I will elaborate the methods for data collection, including other kinds of semiotic resources, such as story books and a wider sample of figurines. For example, I will add cubs and a female lion (since these differ in appearance from the male lion).

Data analysis

Since the aim is two-folded, I will analyze my data in two different ways. Firstly, I will do a multimodal analysis of the group discussion "moving from macro to microanalysis" (Ash, 2007, p. 209), focusing on how material is used as a semiotic resource in meaning making. Secondly, I will use threshold concepts (Meyer & Land, 2003, 2005; Ross et al., 2010) as an analytical framework to analyse the individual interviews in order to look into how pupils explain speciation. In the second analysis threshold concepts will be used in coding the data to see if, and if so what concepts, are in the pupils reasoning despite they do not have had formal education around evolution and speciation. These two ways of analysing data has the possibility to shed light on how education can be focused in order to develop and enhance young pupils' understandings.

PRELIMINARY FINDINGS

In preliminary analyzed data, I can see that six-year-old children are expressing fragments of knowledge about speciation as a result of evolutionary process. For example, the pupils express that crucial aspects for speciation are time, differences in climate, variation within a population, and heredity, which to some extent relate to threshold concepts in evolution (Meyer & Land, 2003, 2005; Ross et al., 2010). Preliminary findings also include that the pupils use the toy figurines, the map and the photographs as semiotic resources in the process of meaning making. In addition, the material is used as a tool for argumentation to support the pupils' ideas in the group discussions.

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THE IMPACT OF SCIENCE CAREER-FOCUSED LEARNING MATERIALS ON STUDENTS' AWARENESS OF AND ASPIRATIONS TOWARDS SCIENCE-RELATED CAREERS

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AN OUTLINE OF THE STUDY

This study addresses the problem of students not considering science in school as relevant and interesting to them (Sjøberg & Schreiner, 2010) and thus not aspiring to a career in science-related fields, as shown by the PISA international study (OECD, 2007). One of the possible reason points to the connection between students´ lack of interest and poor pedagogical practices (Potvin & Hasni, 2014). The current study focuses on determining the impact of interesting and relevant learning materials about science-related careers have on students´ career choices in science-connected fields. The study is being undertaken in three phases:

- 1. Determine aspects of relevance among 77 introductory texts in science-related investigative and decision-making enabling modules;
- 2. Develop an instrument according to relevant literature and introductory text analysis results (1st phase) for evaluating degree of interest and relevance perceived by students through STEM-career related introductory scenarios;
- 3. Pedagogical longitudinal study (two years) using STEM-career introducing learning modules for evaluating the long-term impact on students´ STEM-related career awareness, and career aspirations in the STEM field among 7th and 9th grade students.

Concept map methodology is used in order to determine differences in students´ knowledge structure about STEM-related careers and necessary characteristics (skills, knowledge and personal traits), before and after the pedagogical study. In the current synopsis, the first two phases form the major focus.

REVIEW OF RELEVANT LITERATURE

Interest has been a focus in the context of education for centuries (Krapp & Prenzel, 2011), while relevance has been addressed as a question *"What makes the learning in school relevant to the students´ life and their future?"* from the beginning of the twentieth century (Stuckey et al., 2013). Nonetheless, both interest and relevance, in a science education context, are still a concern, as research is showing a decline in interest towards science through school years (Potvin & Hasni, 2014). Also shown is that attitude towards school science is closely related to students´ aspirations in science (Dewitt & Archer, 2015). There are several explanations for these trends in science education, one of them being the quality and type of instruction students receive during school lessons (for other possible reasons, see Krapp & Prenzel, 2011). One approach to helping students recognize the meaningfulness of science studies is to incorporate STEM-career information, into science teaching, in the form of tasks (Orthner *et al*., 2013), or enabling students to visit STEM-related industries so as to provide authentic experiences (Gebbles, *et al*., 2011; Muscat & Pace, 2013). As shown by Frymier and Shulman (1995), using techniques that indicate the value of study-content to students´, result in higher motivation to study.

Unfortunately, relevance does not have one specific definition and thus has different interpretations by several authors like Keller (1983), Levitt (2001), Van Aalsvoort (2004) and more recently pointed out in a review article by Stuckey *et al.* (2013). Although relevance interpretations vary, this research uses an interpretation by Levitt (2001) in which relevance to students can be described through words like *importance, usefulness and meaningfulness*. This interpretation is used, because the focus of this study is to determine whether student perception, when facing an introductory scenario, is relevant, interesting, neither or both. In this context, perception is used, because cognitive and metacognitive processes are involved.

Under person-object theory of interest, new learning materials for students aim towards developing a sensation of interest. In this situation, the introductory scenarios in such learning materials are the ´objects´, which, when in contact with students, aim to have a perception as interesting (Krapp, 2002; Krapp & Prenzel, 2011). Interest can be divided into situational and individual interest (Hidi & Renniger, 2006) and in this regard, scenario-based interest can be described as a form of situational interest (Hidi & Baird, 1988). Nevertheless, depending on the context built around subject knowledge, students can be interested when the topic covered is individually interesting for some students and perceived situationally interesting by others. Furthermore, introductory scenarios are also trying to link students´ prior knowledge with the need to gain new knowledge. Connecting prior knowledge or experiences with the new information students obtain through interacting with the scenario, has been shown, by Wade *et al.* (1999) as a factor to increase students´ interest. Going further by interlinking relevance and interest and determining their relationship, Hidi and Baird (1986) have made a distinction between ´knowledge-triggered interest´ and ´value-triggered interest´. Knowledge-triggered interest stems from conceptual connections with the information gained and with prior knowledge. Value-triggered interest, on the other hand, stems from the relationship between incoming information and persons´ values, desires and preferences, or goals. Bearing this in mind, it suggests that students need to perceive relevance, in order to find science learning interesting i.e. relevance drives motivation through interest.

RESEARCH QUESTIONS

- 1. What characteristics can be determined in introductory texts intended to be relevant to students (Phase 1)?
- 2. What triggers students´ perception of relevance and/or interest in STEM-career related introductory scenarios (Phase 2)?

RESEARCH DESIGN AND METHODS

During the first phase of this study, a database of introductory text scenarios, containing 77 learning modules for targeting science-related problems and issues in 8-12th grade, were analyzed to determine aspects considered to be relevant for students in the opinion of educators. The database contained learning modules, developed by educators from 21 different European countries. In the frame of the current study, the introductory texts were passages presented to students in science lessons in order to stimulate students' interest for the follow-up inquiry activity and subsequent decision making about the issue or concern presented in the introductory texts, intending to be relevant for meaningful learning (Holbrook & Rannikmäe, 2007). By using contemporary content analysis (Hsieh & Shannon, 2005) the introductory texts were analyzed and characteristics detected which were later organized into three categories, which were subsequently divided into nine subcategories (Table 1).

	Roll of application		**Field of focus**			**Impact range**			
Description of a category	Introductory scenarios can be divided into two subcategories, considering the way scientific or non-scientific (social) concepts are presented. It can be presented through a problem-solving prism or it can be presented as descriptive text and application is used as an example for decoration purpose.		Describes, how concepts are presented, how scientific concepts are framed			Describes on what level students are affected or issue presented affects people.			
Subcategory	Application as an example	Problem solving through application of scientific/mathematical/ social concepts	Scientific	Socio-scientific/-mathematical	Social	Impersonal	Personal	Local	Global

Table 1. Categorization derived from characteristics derived from introductory text analysis

Based on introductory text analysis and drawing from relevant literature, an instrument for collecting data on student perceptions of relevance and interest, perceived through introductory scenario, was developed. This included five sections: a. knowledge triggered interest, b. impact level perceived by students, c. goals (career, studies, desires/dreams), d. value to the scientist community/to the whole society, e. scenario characteristics. Altogether 28 statements were developed, to which students were asked to agree or disagree based on a 4 point scale (1-do not agree at all; 4-totally agree). The statements concerning, whether students perceive the scenario as interesting, likeable, relevant, motivating included additional questions, why students thought so. Before answering the questionnaire, students were shown a video of a scenario, which included STEM- related career information about food microbiology or electricity, set in a context aiming to be relevant to students. The topics, food microbiology and electricity were chosen as STEM-career contexts, as they were strategic priorities for the EU (European Commission, 2012) and whereas the first was considered to be more interesting for girls but less so for boys, the second was vice versa (Teppo & Rannikmäe, 2007).

A convenience sample was formed, consisting of eleven different classes of seventh grade students, from different locations in Estonia, resulting in approximately 220 students, being questioned in February- April 2016. The planned second stage included group interviews, to be carried out after analysis of questionnaire responses to determine, in greater depth, perceptions of relevance and interest through introductory scenarios.

PRELIMINARY FINDINGS

Data collection using the questionnaires and analysis of responses is in process on the time this synopsis is being written.

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INVESTIGATION OF THE EFFECT OF SIMULATION-INTEGRATED ARGUMENTATION-BASED SCIENCE LEARNING ON PRE-SERVICE SCIENCE TEACHERS' CONCEPTUAL UNDERSTANDING ABOUT FORCE AND MOTION IN TERMS OF TASK VALUE

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AN OUTLINE OF THE FOCUS OF THE STUDY

According to the constructivist theory, students link new information they learn to their prior knowledge and construct all of them in a meaningful way by making comparisons (Posner, Strike, Hewson & Gertzog, 1982). The prior knowledge of a student or the misconceptions he/she has constitute one of the major problems in teaching concepts (Driver & Easley, 1978). Posner et al, (1982) indicate that there should be dissatisfaction about an existing concept and a concept that is newly introduced should be intelligible, plausible and fruitful so that the conceptual change can take place in the mind of an individual.

It is necessary that the individual is not satisfied with the existing concepts so that the conceptual change can be achieved (Posner et al, 1982). There needs to be a cognitive conflict for this dissatisfaction or non-conformity to occur and the cognitive conflict in the individual's mind takes place with the clash of opposing ideas (Dole & Sinatra, 1998).

Pintrich, Marx and Boyle (1993) described the classical conceptual change model pioneered by Posner et al. (1982) as "cold conceptual change" whereas Pintrich et al. (1993) introduced the conceptual change model that is affected by affective, motivational and social processes and defined as "hot conceptual change". Recently, the concept of "warming trend" is seen in conceptual change researches (Sinatra, 2005). It is indicated that learning about the world is a process beyond classical accumulation of knowledge and requires to struggle significant conceptual and emotional barriers (Sinatra & Mason, 2013) According to Pintrich et al (1993) such characterictics as personal interest, importance, utility value, achievement goals, self-efficacy, and control beliefs affect the purposive intentional in conceptual change. For example, the participant individuals attaching importance to the results of a topic that is being discussed can be convinced by strong arguments (Johnson & Eagly, 1989). The individuals interested in the topic that is under discussion make more effort during the argumentation process and can elaborate on the concepts and ideas much better (Petty & Cacioppo, 1986; Dole & Sinatra, 1998).

Simulations can be used to create environments where the existing concepts in the minds of students will conflict (Tao & Gunstone, 1999). Simulations provide an opportunity to manipulate the variables and to immediately see the results of factors that they affected or are affected from (Bliss & Ogborn, 1989). They also provide students an opportunity to test hypotheses, discuss their ideas and to find a new point of view according to results (Tao & Gunstone, 1999). Furthermore, it is also considered that simulations can solve the timing problem and provide a quality environment for argumentation because many teachers consider discussion activities as dispensable since they take *time* (Newton, Driver, & Osborne, 1999). Due to the above-mentioned reasons, simulations about the topic of force-motion will be used in the present study.

Force and motion were selected as the topic to study the process of conceptual change. Because there are many misconceptions about force and motion in the literature (Gunstone & Watts, 1985). It is considered that the methods that will be used in the study will facilitate conceptual understanding about force and motion.

In the present study, the effect of simulation-integrated argumentation-based science learning on the conceptual understanding of pre-service science teachers (PSTs) will be investigated. Moreover, the effect of task value on PSTs' conceptual understanding will be investigated in three different groups (control groups, simulation groups, simulation + argumentation groups).

REVIEW OF RELEVANT LITERATURE

Conceptual change requires to compare the existing concepts with new concepts and then to restructure them (Posner et al. 1982). Students should think thoroughly about how a new concept is related to an existing concept (Hynd, 2003). Thinking thoroughly sometimes means "to make a lot of effort" and requires to think deeply about arguments and counter arguments (Dole & Sinatra, 1998). Presenting a justification and asserting claims during the argumentation process leads to a change in the minds of students and it is known that this process facilitates the conceptual understanding of students (Niaz, Aguilera, Arelys, & Liendo, 2002). One of the aims of the present study is to explore how simulation-integrated argumentation-based science learning affects the conceptual change in students.

Computer simulations have been shown to be effective in fostering conceptual change in several studies (Gorsky & Finegold, 1992). Simulations may represent the real world and also eliminate alternative concepts (Tao & Gunstone, 1999).

There needs to be interest, willingness and motivation for students to sustain the argumentation process and sufficient cognitive efforts (Nussbaum & Sinatra, 2003). The mentioned motivational factors affect the conceptual change process considerably except for the dissatisfaction about the existing concept (Pintrich, Marx, & Boyle, 1993). Task value among the motivational factors explains the qualities of different tasks and how those qualities influence an individual's desire to do the task and also involves the interest about a topic (Eccles, et al., 1983). The interest about a topic has an effect on individuals' willingness about constructing an argument or evaluating a counter argument (Dole & Sinatra, 1998). In the present study, it will be investigated how the methods in 3 different groups (control groups, simulation groups, simulation + argumentation groups) affect PSTs' conceptual understanding in terms of the task value.

STATEMENT OF THE RESEARCH QUESTIONS THE STUDY WILL TRY TO ANSWER

The aim of the present study is to investigate the effect of simulation-integrated argumentation-based science learning on the conceptual understanding of PST in force-motion topic. In this regard, the conceptual understanding of students in 3 different groups (control groups, simulation groups, simulation + argumentation groups) will be investigated and the questions given below will be answered:

- 1) Is there any significant difference in the conceptual understanding of PST in the group where 3 different teaching methods (traditional teaching, simulation-integrated teaching, simulation-integrated and argumentation-based learning) were used, in terms of the force-motion topic, after the teaching treatment?
- 2) How is the conceptual understanding of PST (before and after the treatment) with different levels of task values, in the groups where traditional, simulation-integrated and simulation-integrated argumentation-based learning were employed in lessons?

OUTLINE OF THE RESEARCH DESIGN AND METHODS

Mix methods will be used in the present study. Pre-service science teachers 3rd graders will be randomly distributed into 3 groups which are traditional teaching, simulation-integrated teaching and simulation-integrated argumentation-based science learning groups. Traditional teaching will be employed in the control group while simulation-integrated teaching will be used in the first experimental group and simulation-integrated argumentation-based science learning will be used in the second experimental group. In all of the 3 groups, the topic of force-motion will be taught. Simulations and the argumentation activities will be determined taking into account the most common misconceptions in the force-motion topic. In the group where simulation-integrated argumentation-based science learning is practiced, the “Predict-Observe-Explain (POE)” approach will be used. The structure of the argumentation will be examined according to Toulmin model.

The quantitative data of the study will be obtained from the part that is designed as a quasi-experimental study. In each of the 3 study groups, the Force Concept Test will be administered as a pre-test/post-test - delay test. In this regard, students’ misconceptions regarding the topic of force-motion will be determined. Also, PSTs’ task value will be determined both before and after the treatment, using a measurement tool that will be developed specifically for the force-motion topic. With the use of this task value scale, PST will be categorized in 3 groups being of low, medium or high task value.

As for the qualitative part of the study, there will be interviews consisting of open-ended questions regarding the determined misconceptions. The first interview will be held with the PST divided into specific categories after the FCI and the task value scale were administered. According to the FCI, students will be divided into 4 categories in terms of their conceptual understanding: having misconceptions, having false knowledge, having scientific knowledge and having a lack of knowledge. According to the task value scale, there will be 3 categories being low-medium and high task value. 4x3=12 students in this category will be interviewed before and after the treatment and the answers and justifications they give for these target misconceptions will be elaborated. In total, 36 students - being 12 from each of 3 different teaching groups - will be interviewed. For example, the misconceptions of a student that was determined to have misconceptions before the treatment and a high task value will be investigated in the control group. It will also be investigated whether the student retained the misconception or acquired the true/false scientific knowledge or had a lack of knowledge. In this regard, it is aimed to explore the relationship between task value, different methods and conceptual understanding. More clearly, it will be determined how and to what extent different teaching methods are effective and what the task value level of individuals should be in order to get effective results.

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SESSION O: OTHER

HOW TO ENHANCE THE STRIVING FOR KNOWLEDGE AND SELF-RELIANCE OF HIGHLY ABLED AND GIFTED PRIMARY SCHOOL CHILDREN IN A SCIENTIFIC OUT-OF-SCHOOL LEARNING-CONTEXT?

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FOCUS OF THE STUDY

The aim of this research-project is to figure out factors of a learning-context that enhance the striving for knowledge and self-reliance of highly abled and gifted primary school children in out-of-school science courses.

To get a look into those courses, the presented research study is allocated to a co-operation-project between the University of Education Heidelberg and the Kinderakademie Mannheim – an academy for highly abled and gifted primary school children. All children participating in the academy are tested and identified as highly abled or gifted, what means they achieved an IQ of 130 or higher in an official intelligence test. The academy´s aim is to support these special children in different ways out of school by satisfying their special needs. To do so, the Kinderakademie offers a manifold programme of gratis courses within different disciplines. The duration of these thematic courses expands from October to May. The children can choose a specific course for participation – matching their interests. The results of this research-study will be connected to an evaluation of the courses addressing some criteria of the individual needs of the children (striving for knowledge and self-reliance).

RELEVANT LITERATURE

We identify striving for knowledge and self-reliance as the "Erkenntnis- und Selbstständigkeitsstreben" described by Lehwald. In his opinion the striving for knowledge (Erkenntnisstreben) as well as the striving for self-reliance (Selbstständigkeitsstreben) are remarkable aspects of highly abled and gifted children (see Lehwald, 1981, 1985, 2009, 2010). In his work these aspects are not only an important factor for the identification of abled children but also for the preparation of learning-contexts to enhance the giftedness (ibid). Lehwald defines the "Erkenntnis- und Selbständigkeitsstreben" as a type of habitual motivation (Lehwald, 1985, p. 38) and insofar as a personality trait, that shows a remarkable behaviour in the transaction with other variables within the situation (see ibid, p. 19), understood as a mutual influence (ibid, S. 19). In that way, the striving for knowledge and self-reliance become basic motivation for learning as well as a personality trait (see ibid).

One can find the situated motivation in almost all psychological dynamic models of giftedness. Gagné calls it "intrapersonal catalyst" (see Feger & Prado, 1998, p. 39), Mönks defines it as a "factor" (vgl. Mönks & Ypenburg, 2000, p. 23) and in the model of Heller the situated motivation is introduced as a non-cognitive personality trait, a so-called moderator (see Heller, 2001, p. 24).

Lehwald argues that the striving for knowledge and self-reliance as a personality trait can be seen in the following behaviours:

- preferring self-reliant and cognitive work,

- affective and emotional working on problems,
- tendency not to give up and overcome difficulties,
- a never ending interest in information,
- interest in complicated work that needs flexible thinking (see Lehwald, 2009, p.11).

Those aspects also can be found in variations in the works of Deci and Ryan about the intrinsic and extrinsic motivation especially within learning-situations (see Deci & Ryan 2000). Lehwald itself talks about striving for knowledge and striving for self-reliance as intrinsic motivated actions (see Lehwald 2009).

In a further step, we understand that a personality trait divides itself in different aspects of the person and so into “elements of being” (see Trautmann 2008). If these elements fit together with an extraordinary predisposition (giftedness as a cognitive disposition), an effect taking environment and the evolving self in a positive combination and surrounding (family, school, peer group, media), the internal giftedness can be an external one and can be lived by the child. This model of giftedness, the so called “Mikadomodell” (Trautmann, 2008) is not only a dynamic but also a pedagogical and interventional one and because of this, it is our preferred model for the research project. Our study focuses on the situational intervention possibilities to enhance the striving for knowledge and self-reliance in the science courses of the Kinderakademie. Furthermore, this model includes the basic thinking of interaction between the child and its situated context, which is also fundamental for Lehwald´s work.

RESEARCH QUESTIONS

According to the outlined theory above, we are investigating interaction-processes between the gifted children and their learning-contexts while acting in the science courses in order to find factors that enhance the striving for knowledge and self-reliance. In this context, the enhancing shall not be understood as a remarkable development within the course-time but as the opportunity and the freedom for the children to develop their giftedness. The learning-context we define as the sample of the learning-material offered to the children, the room with its opportunities and the interactions with the course-instructor. So we are looking for interaction-processes with the following three-step approach:

- 1. Behaviour of the child that shows a striving for knowledge and self-reliance,
- 2. Reaction of the learning-context to that behaviour,
- 3. Reaction of the child to the contextual reaction.

By finding, analysing and interpreting those three-step-interactions, we want to give answers to our research question:

- What are the factors of a learning-context that enhance the striving of highly abled and gifted children for knowledge and self-reliance?

To answer this question we must have to go three steps: First, we have to locate sequences, in which we can see behaviour/actions of highly abled children representing their striving for knowledge and self-reliance. Secondly, we have to describe, what kind of reactions the learning-context shows to that striving of the children. Thirdly, we have to decide, whether or not the children hold on the striving or end up with it as a reaction of the intervention of the learning-context before.

RESEARCH DESIGN AND METHODS

Accordingly to the steps described above, we started a qualitative analysis of interactions based on video data. We are taking video recordings of different science courses and analyse them in two steps: At first, we search the video data for the striving behaviour of the children applying the CBAV method (see Niedderer et. al., 1998). To do so, we transform the behaviour described by Lehwald (e.g. the Items of the FES-questionnaire, Lehwald 1985) into categories and identify operators for them; so we end up with a manual to do this first step of analysis by a category based event-sampling. To get reliable results we started this step with two more decoders.

Now, having identified situations of striving, we can go the second step and analyse these "filtered" data in a much more detailed way: Here, we apply the sequence analyses as explained by Dinkelaker und Herrle (2009). This method is a reconstructive form of interaction-analyses in which the three-step-interactions (as described above) are separated and every single step and so every single behaviour/reaction is addressed with various possible situated interpretations by different observers. Doing that, we get a variety of different interpretations of the single behaviours and reactions. Having this, we are able to look backwards and see what interpretations fit together so that there evolves a chronological, consequent and logical way of behaviour and reactions as parts of interaction-processes. On this basis, we will hopefully be able to identify the factors of a learning-context enhancing the striving of highly abled and gifted primary school children for knowledge and self-reliance.

PRELIMINARY FINDINGS

At the time of the application for the 2016 ESERA summer school, the theoretical part of the study is about finished; a first version of a catalogue of categories for the observing is developed and tested using three different examples of videotaped course sessions. Up to May 2016 we will record about 10 course sessions (duration: 90 minutes each). In parallel, the systematic video analyses planned are realized.

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ELEMENTARY TEACHERS' IMPLEMENTATION OF NOVEL ENGINEERING TEACHING MATERIALS IN SCIENCE CLASSROOMS: BELIEFS AND PRACTICES

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INTRODUCTION

Despite many years of research on school reform, fidelity of implementation of new engineering pedagogy has been a continuous concern. For instance, a recent publication indicates that newly designed project-based mathematics curriculum materials were not carried out in the classroom in the way envisioned by the developers (Han, Yalvac, Capraro, & Capraro, 2015). Fidelity is the conformity between a pedagogical theoretical framework and what is actually being implemented in the classroom (Gresham, MacMillan, Beebe-Frankenberger, & Bocian, 2000). Recent studies (Capraro et al., 2014; Darling-Hammond, 2000; Darling-Hammond & Youngs, 2002; Goldhaber, 2002; Rice, 2003; Wayne & Youngs, 2003) have shown that increased fidelity of implementation (FOI) yields enhanced students' learning outcomes.

The curriculum developers assume that heightened fidelity between the expected methodology and actual teaching practices will lead to improved student performance; but to date there has been no study of the fidelity between ideal and actual practice. Because of this void in the literature, this study will examine the fidelity of implementation of the engineering curriculum by elementary teachers. In order to do so, it is important to explore teacher attitudes and behaviors towards implementing new curriculum (i.e. to what extend the teacher's actual teaching in the classroom align with the teacher's report in their teaching?, self-perceptions of how well they implemented the engineering curricula practices). Consequently, the purpose of this dissertation is to examine the degree to which the fidelity of implementation the novel engineering curriculum impacts teacher instruction, as well as teachers' reports (e.g. STEM Questionnaire, FOI Teachers Logs) and teachers' attitudes (e.g., Teacher Attitude Survey). Therefore, the researcher purposes to investigate what the FOI log captures and misses (i.e. validity) and whether teacher self-report is reliable.

LITERATURE REVIEW

Engineering Education

Engineering education is fairly new to K-12 school curriculum in the United States. To date, there have been several studies conducted to implement the idea of engineering and its practices into science, technology and mathematics classroom environment (e.g., Cantrell, Pekcan, Itani, & Velasquez-Bryant, 2006; Hunter, 2006; Mayo, 2007; Sánchez & Olivares, 2011). Several educational researchers (Bybee, 2013; Czerniak, 2007; Uttal & Cohen, 2012; Smith, 1982; Van Haneghan, Pruet, Neal-Waltman, & Harlan, 2015) and cognitive scientists (Bruning, Schraw, Norby, & Ronning, 2004) have been studying how K-12 students and teachers can understand the main concept of engineering phenomenon. At the same time, researchers are interested in looking at the impact of engineering practices on K-12 teacher practice and how those practices affect students learning (Fang, 1996; Nespor, 1987). Consequently, the presence of engineering in K-12 has become highly important and accepted widely by educators, policy makers, and industry leaders that teaching and emphasizing more on the "E" component in science, technology, engineering and mathematics (STEM) subjects in the schools must be improved and enhanced immediately.

One such novel pedagogical approach is the Engineering is Elementary (EiE) curriculum that now reaches millions of elementary students and their teachers in the United States. This curriculum fits with the various national, state, and local science, technology, engineering, and mathematics (STEM) standards. The curriculum includes highly developed lesson plans, teacher practices, and student activities (Lachapelle & Cunningham, 2010). Teachers preparing to teach the engineering curriculum attended a professional development workshop at the beginning of the school year to be trained in the best uses of the program.

Teachers' Beliefs and Practices

There is a substantial literature on teacher beliefs and the impact of their beliefs on students learning and academic achievement in science, mathematics, and technology (e.g., Cross, 2009; Ertmer, 2005; Riggs & Enochs, 1990; Van Haneghan et al., 2015). Furthermore, the existing body of research in this arena has yielded significant results that highlighted, the essential role of teacher beliefs and practice carries on student outcomes (Fang, 1996; Nespor, 1987).

However, there is a few studies in engineering education (e.g., Nathan, Tran, Atwood, Prevost, & Phelps, 2010; Phelps, Nathan, Atwood, Prevost, & Tran, 2009; Yasar, Baker, Robinson-Kurpius, Krause, & Roberts, 2006). According to Pajares (1992), beliefs are the "best indicators of the decisions individuals make throughout their lives" (p. 307). A research finding showed that there is a significant relationship between the teacher beliefs and practices (Kagan, 1992).

While teachers are highly responsible to increase their students' achievement and interests in STEM fields (Nugent, Kunz, Rilett, & Jones, 2010), most of the time, they are typically afraid, or they lack the confidence to use engineering practices inasmuch as they might prefer not confront the questions of talented and creative students (Felder, 1988) due to the fear of not answering correctly. Teacher teaching experience is one of the major factors in attracting students to STEM majors and retaining them in the majors. In further, classroom experience enhances students' knowledge of the major and career to prepare them for their professional goals.

RESEARCH DESIGN

Research Questions

In this converging parallel mixed method design (see Appendix A), there are three main overarching questions.

1. What is the relationship between teachers' self-perception and pedagogy?
2. How do teachers describe their teachers' characteristics (e.g., beliefs) as relating to an ideal engineering model?
3. How does the quantitative and qualitative findings come together to explain the concept of engineering implementation by elementary teachers?

Rationale for Mixing

A convergent parallel mixed method research design will be utilized to answer the research questions. In order to investigate further evidence-based practices within the proposed research, integrating objective data with subjective data can provide an expansion of evidence used to better evaluate the research question and to gain a greater understanding of complex phenomenon (Chatterji, 2005; Denscombe, 2008; Johnson, & Onwuegbuzie, 2004; Palinkas et al., 2011). A quantitative research methodology tends to address specific questions with measurable data such as focusing generally on a specific aspect of behavior (Leedy & Ormond, 2005) and intend to see how well the data supports or contradicts an existing theory (Creswell & Plano-Clark, 2011). However, a qualitative research methodology tends to understand teachers' perspectives in relation to a certain situations (Creswell, 1998). The researcher operates this design to investigate multiple aspects of and gather harmonizing data concerning the multifaceted characteristics of fatigue (Creswell & Plano Clark, 2011). The qualitative data and their analysis refine and explain those statistical results by exploring teachers' beliefs and practices in more depth (Cresswell, 2013; Rossman & Wilson, 1985; Tashakkori & Teddlie, 1998).

Sample

This study uses archival data previously collected and derived from a sample of 289 elementary teachers recruited by the EiE research team at Museum of Science, Boston through an approved IRB protocol. The participants are from over a two-year, between 2013-2015, federally funded research studies of elementary engineering curricula. All datasets were based on the convenient sampling. The majority of the teachers were primarily female, white, and non-Hispanic or Latino.

DATA MEASUREMENTS & ANALYSIS

Quantitative

There are two quantitative data sets will be used in the study. (1) The Teacher STEM Questionnaire was created by Cunningham, Lachapelle, and Keenan (2010) to investigate teachers' ideas about engineering and technology conceptual change and their attitude towards STEM. The internal consistency of the pre-survey items was reported as excellent overall with a Cronbach's alpha=.9 whereas post-survey reported Cronbach's alpha=0.88. (2) The Teacher Attitude Survey was developed by Lachapelle et al., (2014). The internal consistency of the Pedagogy for Teaching Engineering scales was reported overall of Cronbach's alpha=.79. Both instruments will be used to analyze the relationship between the study variables. IBM SPSS Statistics version 22 software will be utilized to calculate descriptive statistics and AMOS will be utilized to compute CFA for the quantitative analysis of the model fit.

Qualitative

There are also two qualitative data sets will be used in the study. (1) Fidelity of Implementation (FOI) Teacher Log is to measure the degree of implementation in the classrooms. After implementing a specific engineering EiE lesson in their classroom, teachers need to complete an online log specified to each lesson as soon as the class is over. (2) Videotaped Classroom Observation allows researcher to analyze a videotaped of the dynamics in the classrooms to gain valuable insights into qualitative data by observing what actually teachers think (beliefs) they do is what actually they did (practice). In terms of analysis, the researcher will observe analyze the videos based on a validated rubric to analyze the teachers' actual teaching videos to observe teachers practice at their classroom in order to determine the degree to which the ideal engineering model was being implemented with fidelity. In addition, the teachers' report and attitudes were examined. "Sampling to achieve comparability across different types of cases on a dimension of interest" (Teddlie & Yu, 2009, p. 80).

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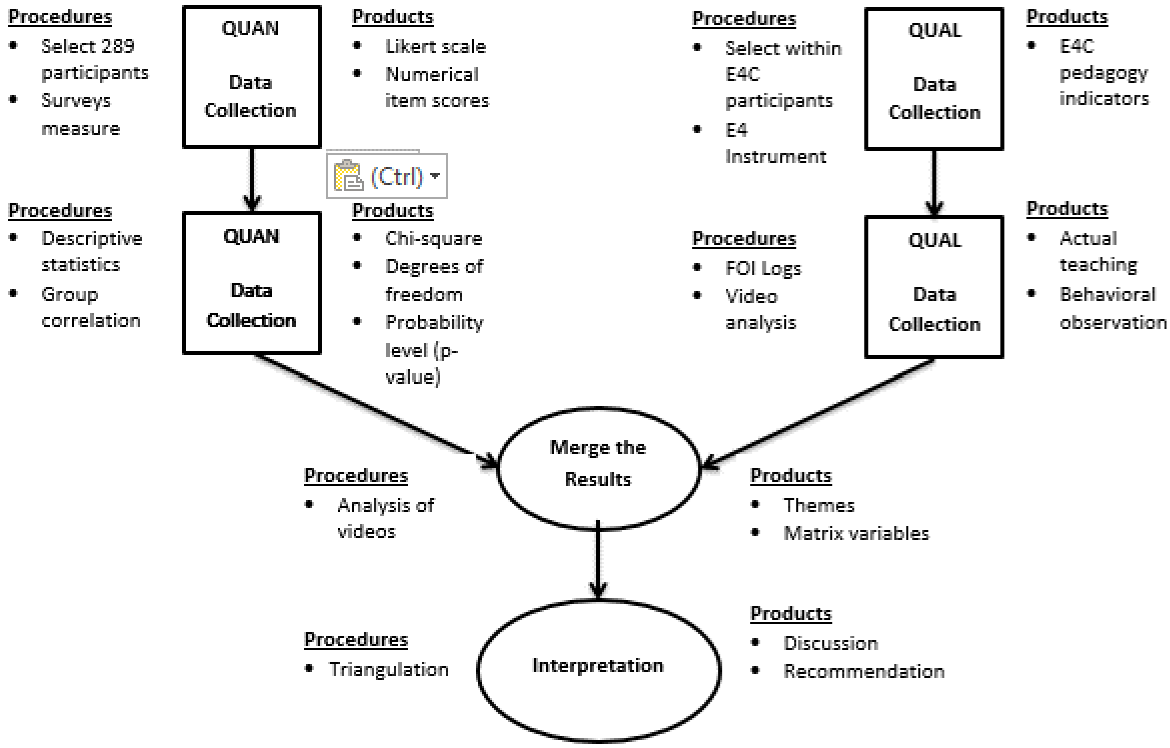
APPENDIX A – DIAGRAM FOR CONVERGENT PARALLEL MIXED METHOD RESEARCH DESIGN



SESSION P: PHYSICS EDUCATION

DEVELOPMENT OF A COMPUTER-BASED ASSESSMENT OF PHYSICS TEACHERS' EXPLAINING SKILLS

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FOCUS OF THE STUDY

My study focuses on teacher's explaining skills (ES), a particular aspect of teachers' professional competences. Although explaining situations are an important part of teachers' actions in classroom, very few studies deal with this topic (Geelan 2012). Moreover, explaining science in classroom is one of the biggest challenges for teacher trainees (Merzyn, 2005). In prior studies a valid but time-consuming performance test for ES was developed, based on the video analysis of teachers actually explaining science to students in a standardized setting (Kulgemeyer & Tomczyszyn, 2015). Starting from this setting, I aim to develop a computer-based interactive video vignette test, thus closing the gap between the performance test (high validity but high effort) and standardized paper-pencil tests (low effort but low validity). This new test is meant to be applicable in large-scale assessments. It would enable us to investigate the relationship between teachers' ES and students' learning achievements and therefore contribute to the measurement of teaching performance in general.

REVIEW OF RELEVANT LITERATURE

My theoretical framework builds on a constructivist understanding of the process of explaining. I agree with Gage's (1968) notion of explaining as the "skill of engendering comprehension" as well as Treagust's and Harisson's (1999) concept of *science teaching explanations*, which, in contrast to *scientific explanations,* emphasizes the didactic purpose to foster an addressee's (e.g. a student's) understanding of scientific content. This has led to the constructivist communication model for explaining by Kulgemeyer and Schecker (2013) as shown in Figure 1: In this model, the ES of an explainer (e.g. a teacher) who wants to explain scientific matter to an addressee (e.g. a student) is understood as the ability to prepare scientific content in a way that the addressee has the opportunity to engender comprehension. Thereby the explaining has to be both *subject-oriented* (that means basically scientifically correct) and *addressee-oriented* (which implies the consideration of the addressee's previous knowledge and interests). To do so, the explainer can modify four aspects of an explanation: (1) the context or examples he/she uses, (2) the language code (e.g. every day language vs. scientific language), (3) the representation form (e.g. using pictures, diagrams etc.), and (4) the level of mathematics (e.g. formulas). The addressee responds to that attempt of explaining with a feedback and may thereby invite the explainer to modify the explanation. In this understanding explaining is a constructivist process and should not be confused with a teacher-centered way of teaching or as a means to "transfer" knowledge directly (Kulgemeyer and Schecker, 2013).

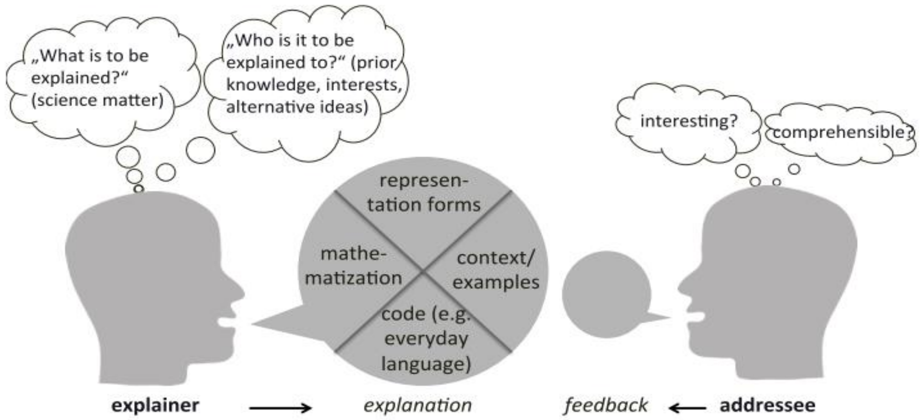

Figure 1: Model for explaining in science communication adapted from Kulgemeyer et al. (2013)

As described in Riese et al. (2015), ES can be seen as a part of teachers' professional competences, influenced by both content knowledge and pedagogical content knowledge. Miller (1990) divided the assessment of professional competences into four categories with respect to an increasing level of actual professional action: testing for knowledge, testing for competence, testing for performance and testing for action quality. Whereas testing for action quality takes place in real situations (e.g. videotaped teaching in classrooms), performance tests are set in controlled, standardized situations. Competence tests evaluate whether a test person knows how to master professional problems usually by written tests. Knowledge tests are written tests too, focusing on the declarative knowledge that is required to act in a professional way.

Although written tests provide the lowest level of authenticity, they have been used most frequently for assessing professional competences or knowledge in recent research projects as they enable large-scale assessments. However, with regard to validity (authenticity has an influence on validity), assessment methods beyond written tests are needed (von Aufschnaiter and Blömeke, 2010). Success on written tests may not be a good predictor for action quality in real situations. Testing for performance rather than for knowledge may be the better choice (Miller, 1990).

The "Dialogic Explaining Assessment (DEA)" developed by Kulgemeyer and Tomczyszyn (2015) is an example of such a performance test. In this standardized setting an explainer is videotaped in his/her attempt to explain a given topic (e.g. "Why does one feel weightless in a roller-coaster?" or "How can the earth be protected against an approaching asteroid?") to a student. The test person has a given time of ten minutes to prepare the explanation, using various provided materials (e.g. diagrams). After the preparation, he/she explains the topic to the addressee in another ten minutes. The addressee is trained to use standardized prompts in his/her feedbacks, such as "can you provide another example for what you mean?". The explaining is videotaped and analyzed afterwards using a set of categories for good explaining. Kulgemeyer and Tomczyszyn (2015) report that a quality index based on these categories forms a valid and reliable scale. However, the collection and analysis of data is very time-consuming and hardly applicable in large-scale assessments.

Competence tests based on video vignettes, on the other hand, have been described as promising for measuring teachers' professional competences in large scale assessments (Rehm and Bölsterli, 2014), but unlike performance tests their lack of interactivity misses an important component of actual teaching (Lindmeier, 2013).

RESEARCH QUESTIONS

The main research questions of my study are:

1. How can explaining skills be measured using a standardized, interactive computer-based test instrument? (cf. Figure 1, Milestones (MS) 1-4).
2. Are there empirical indicators for an impact of a science teacher's ES on his/her students' achievements in explaining situations (predictive validity)? (cf. Figure 1, MS 5).

RESEARCH DESIGN AND RESEARCH METHODS

As described above, a video vignette test seems to be a promising tool for measuring ES in a standardized setting. Therefore I produce video vignettes based on explanations observed in the previous DEA study by Kulgemeyer and Tomczyszyn (2015) and implement them into an online survey environment. For this assessment, several content variations of the test, dealing with explaining different topics in physics, will be realized. Each variation consists of a video showing a script-based scenario in which a teacher is shown who tries to explain a particular topic to a student. The video stops when the teacher has to respond to feedback or a question by the student. The test person then has to choose the best way to continue the explaining process from a given set of standardized responses and is also asked to reason the choice (two tier items). Afterwards the video continues, showing the teacher's actual reaction. Thus the explanation goes on, leading to the next response item. While each item can be assorted to one of the four variables of the explaining model (c.f. Fig. 1), all the items together cover the whole model to ensure content validity.

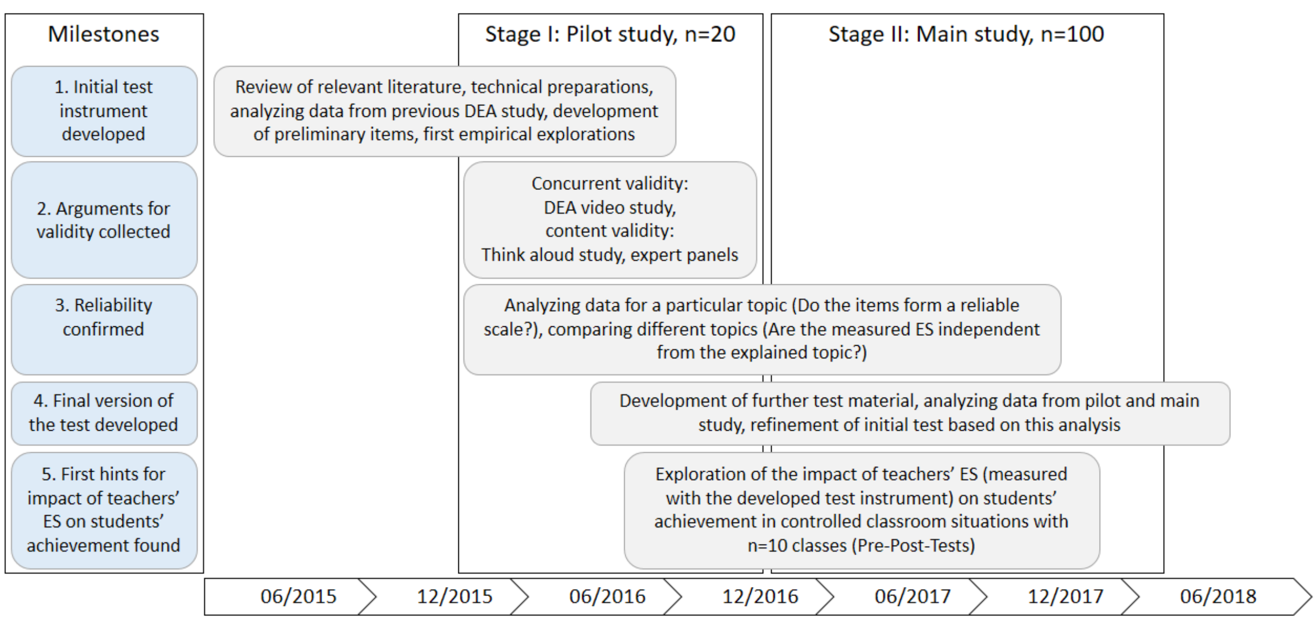

Fig. 2:Design of my research

As shown in Figure 2, my study is divided into two stages. *Stage I* – the pilot study – deals with exploring an initial test instrument. The main goal in this stage is to ensure the validity of the assessment (MS2). With respect to concurrent validity, a number of approx. 20 test persons (teacher trainees) are asked to complete the initial test instrument as well as the DEA instrument from Kulgemeyer and Tomczyszyn (2015). As the DEA instrument has been found to fulfill major aspects of validity, an analysis of correlations is the best way to ensure concurrent validity. Concerning content validity, a panel of experts will be asked to agree on appropriate answers in the test. Furthermore, a think aloud study will be conducted to gain information about what is going on in the test persons' minds while performing the test. The results will be used to develop further test material for additional topics.

In *Stage II*, reliability will be confirmed (MS3). This includes the analysis of data from approx. 100 test persons (teachers). First of all, the items concerning a specific topic need to form a reliable scale (e.g. Cronbach's α). It will also have to be confirmed that the diagnosed level of ES is independent from the explained topic, while the diagnosed level of ES should highly correlate across topics. This will lead to the final test version (MS4, RQ1). The second issue faced in *Stage II* is to gain indicators for a positive effect of teachers' ES on students' achievements in real classroom situations (MS5, RQ2). In terms of predictive validity the diagnosed level of teachers' ES should predict students' level of knowledge after being explained a certain topic. Ten classes will be examined by pre-post-tests, with an intervention of teachers explaining an easy physics topic. This part of the study should rather be understood as an explorative approach to generate hypotheses for further studies.

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LEARNING ABOUT ENERGY WITH WORKED-OUT EXAMPLES AND FEEDBACK

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THEORETICAL BACKGROUND

In his widely quoted book Hattie summarises the empirical research on the effects of various educational influences and interventions on students learning. Hattie reveals that worked-out examples and especially feedback are powerful tools to support students learning (Hattie 2009). The challenge is now to implement such effective tools in the classroom and to prove whether they work effectively in the context of regular physics teaching. In our research project we chose the central physics topic energy (1) and focus on learning with worked-out-examples (2) with feedback (3). All three aspects (1), (2) and (3) are described in the following:

1. Energy Concept

Energy is one of the most important ideas in physics and is also a basic concept in physics education. Many studies prove that the insight of the Physics Energy Concept is difficult for students and many misconceptions can be found (e.g. Duit 2014). A number of studies investigate learning progression in the context of energy (e.g. Neumann et al. 2012) and show that there are different levels regarding the students' insights about the different aspects of the Physics Energy Concept. The aspect of energy conservation seems to be the most difficult. Therefore, fostering a deeper understanding of energy conservation is still a challenge and an unsolved problem at least in secondary school.

2. Worked-out examples

Worked-out examples are a suitable tool for learning scientific concepts and problem solving. Numerous studies prove the efficiency of learning with worked-out examples in different domains (Atkinson et. al 2000). Further studies show that the efficiency of this method depends on the quality and quantity of self-explanations (Lind et al. 2004). In this context, it is interesting that besides the quantity, the quality of self-explanations can be fostered through prompts depending on the students' prior knowledge (Mackensen-Friedrichs 2009). Despite of these findings this method is rarely used in regular physics teaching in secondary schools (Hilbert *et al.* 2008). In addition, there are some outstanding issues: the implementation of worked-out examples in regular physics classes is not investigated in detail; laboratory experiments and studies with upper-secondary and college students are mainly found.

3. Feedback

Learning with worked-out examples means that the students deal on their own with the teaching content and have to take responsibility and control of their own learning. Even when they are prompted to self-explain illusions of understanding can arise (Lind et al. 2004). In this regard feedback seems to be an appropriate tool to promote students learning. To foster students learning progress, feedback should give content-related information - for example by written comments - to the students about their learning level and give guidance how to improve the individual learning process (Black 2004, Hattie 2009). But how does feedback impact the learning with worked-out examples? In this regard it is interesting to consider whether students can self-assess their learning process while working with worked-out examples or if feedback given by the teacher is necessary.

In the light of the above we developed a computer-assisted learning environment on the basis of worked-out examples. In addition the learning environment is accompanied by portfolios to enable different feedback approaches.

RESEARCH QUESTIONS

Against this theoretical background we consider the following research questions:

- What impact do different kind of prompts have on the learning progress of students with medium prior knowledge?
- What impact does different kind of feedback have on students learning progress?
- Does feedback compensate inappropriate prompts?

In addition:

- Can a computer-assisted learning environment on the basis of worked-out examples be used as an effective learning tool in regular physics teaching?
- How do students evaluate learning with worked-out examples over an extended period of time?

PILOT STUDY

The learning environment consists of six worked-out examples which use the energy approach for problem solving. The students are guided through the examples by a program running on tablet computers. We developed two different sets of prompts: one set addresses novices and the other one experts.

Evaluation of the worked-out examples and implemented prompts

The learning environment was tested in a regular physics class (10th grade, 25 students, two hours a week during a period of six weeks). We collected data from log files (text fields, diagrams etc.). In addition, the students answered a questionnaire regarding the acceptance and comprehensibility of the learning environment.

Test development

In order to find out to what extent these worked-out examples support content-related competencies we developed and validated an energy test which is strongly related to the learning targets of the worked-out examples. For test development we assumed that there are four levels of understanding towards a sophisticated insight into the Physics Energy Concept (Duit 2014, KMK 2013). The test was carried out in seven classes of 9th and 10th grade (N = 167). For data analysis we used Rasch modelling (Winsteps 3.81.0).

PRELIMINARY FINDINGS

Evaluation of the learning environment:

The evaluation of the integrated data processing, functionality and acceptance of the learning environment was mainly positive: Fig. 1 displays aspects of the students' acceptance. Fig. 2 displays the comprehensibility of the worked-out-examples and difficulties with the implemented experiments. It is shown that the learning-level suits most students and that the learning environment enables the students to learn at their individual learning speed. However, some students seem to have difficulties while experimenting.

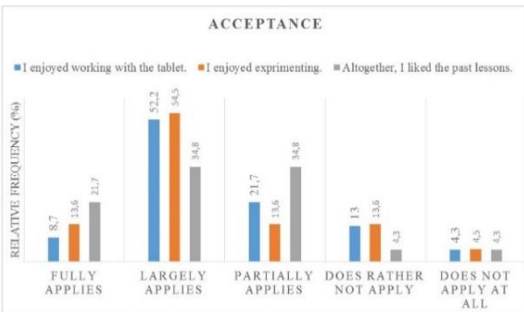

Figure 1: Evaluation of the computer-assisted learning environment - relative frequency of items regarding the acceptance.

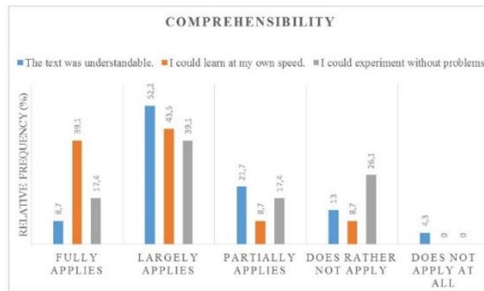

Figure 2: Evaluation of the computer-assisted learning environment - relative frequency of items regarding the comprehensibility.

Energy test – characteristics and results:

The Wright Map shown in Fig. 3 displays the distribution of item and person measures. The vertical axis represents item difficulty as well as person ability. On the left side the students represented by rhombuses are put in order according to their ability and on the right side the test items - characterised by number - are put in order according to their difficulty. In addition, the test item measures are split up according to the assumed four levels of understanding of the Physics Energy Concept. Mean personal ability and mean test item difficulty are marked by *M*. As *mean item difficulty* was set at zero logits, *mean person ability* was calculated at 0.07 logits. It is shown that the average item difficulty and average person ability are close. Mean standard error (marked by *S*) of person ability was determined to be 1.30 logits and the mean standard error of item difficulty to be 1.36 logits. The Wright Map reveals that *item difficulty* and *person ability* measures are well-distributed over the range of measures, but there is a gap between the test items 27 and 26.

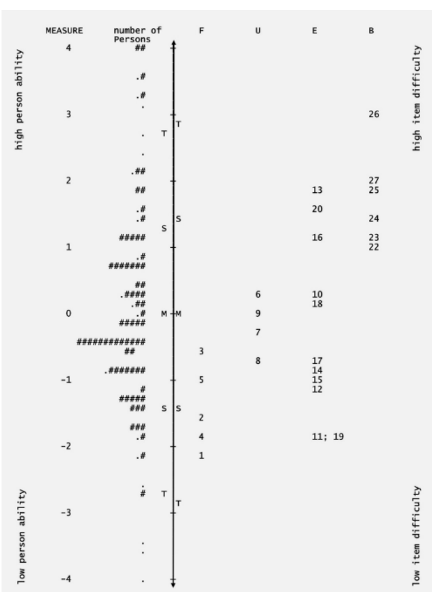

Figure 3: Wright map for 27 test items

Conclusions for the main study:

The evaluation of the computer-assisted learning environment shows that it is generally suitable for students of 9th / 10th grade. On the basis of the collected students' text entries the worked-out examples and prompts were revised and adjusted and an instrument for measuring the students' learning progress was developed and validated. The accordance of *average person ability* and *item difficulty* indicates that the test suits the students' abilities. On the basis of the results we were able to select appropriate items for a pre- and post-test for the main study.

MAIN STUDY

The impact of worked-out examples and feedback will be evaluated in a pre- and post-test design with six different intervention groups. Therefore, the learning environment will be used in about 15 regular physics classes (9th grade, ~300 students). The procedure of the intervention is shown in the Fig. 4.

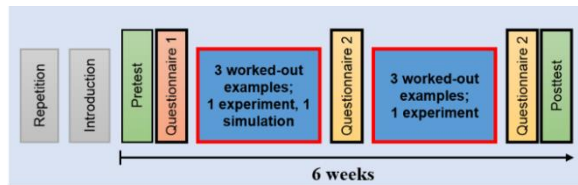

Figure 4: Procedure oft the intervention

The students work through six worked-out examples in their own speed. Furthermore, they answer a questionnaire 1 regarding their self-concept and interest in physics (based on Engeln 2004), a questionnaire 2 regarding the acceptance of the learning environment as well as self-efficacy (based on Seidel 2003). In order to find out to what extent these worked-out examples support content-related competencies we work with pre- and post- tests (energy test, see above). The following table displays the six different intervention groups.

	Self-feedback	Written feedback by the teacher	Without feedback
Prompts 1 (nov)	N ~ 40	N ~ 40	N ~40
Prompts 2(exp)	N ~ 40	N ~ 40	N ~40

Table 1: Study design

For the study we used up to 34 tablets with wireless access to a single server in each class. In addition we collect data from log files (text field, diagrams etc. generated by the students).

CURRENT STATUS AND OUTLOOK

Up to now we have carried out the intervention in 8 physics classes (9th grade, N ~170). More data will be available by the time of ESERA summer school. For analysing the students log files (text entries) a category system is going to be developed. I expect to get further ideas on the evaluation and interpretation of the data and learn more about different kinds of methods for analyzing qualitative and quantitative data during the summer school 2016 due to the exchange with other researchers. Furthermore, discussing preliminary findings and different research approaches in the context of learning scientific concepts will lead to a more elaborated PhD-study and will broaden my view on science education.

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SCIENCE TEACHER STUDENTS' AND PHYSICS TEACHERS' VIEWS ON PROFESSIONAL KNOWLEDGE

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FOCUS OF STUDY

In this qualitative study, I explore how four groups of teachers reflect upon the professional knowledge required to be a good teacher of science or physics in secondary school: 1) teacher students enrolled in a 5-year programme leading to a masters' degree in science teaching (this group has not yet decided in which discipline they will specialise); 2) final-year teacher students in the same programme; 3) novice physics teachers; and 4) experienced physics teachers. Further, I will try to identify what it means to be an experienced teacher and what reflections teachers make about their classroom practice with regard to their toolbox of pedagogical knowledge and content knowledge. The identification of pre-service teachers', novice teachers' and experienced teachers' view on own practice might help to further develop a pre-service teacher education strategy and first-year in-service follow up schema.

This study is part of the ReleQuant Competence project financed by the Norwegian Research Council and led by the Department of Physics at the University of Oslo. The project collaborates with the Norwegian University of Science and Technology (NTNU) and the Norwegian Centre for Science Education. The primary objective of the project is to (ReleQuant Competence, 2014) *develop the research, innovation and teaching competence of three practitioner groups: physics education researchers/teacher educators, practicing physics teachers, and teacher students. This is achieved through collaborative research and development related to teaching resources in modern physics for upper secondary school.* (p. 2)

The particular study of teachers' conceptualisation of professional knowledge described herein is a background study to support the investigations of teacher professional competence in the ReleQuant Competence project.

LITERATURE REVIEW

Shulman (1987) studied the transformations of teachers from being students, through neophytes to veteran teachers and coined the term pedagogical content knowledge (PCK). In her review study on professional growth among pre-service teachers and beginning teachers, Kagan (1992) was able to identify some common features on professional growth and drew a model from her findings. She also confirmed earlier models proposed by e.g. Berliner (1988). Other studies like that of Angell, Ryder, and Scott (2005) investigated the development of conceptual and pedagogical knowledge of novice physics teachers and did comparisons between this group and expert teachers. Their initial findings suggested a different approach to teaching "in terms of pedagogical thinking and practice" where the expert had more focus on the pedagogical tools and communications with the students while the novice teacher had an authoritative approach (Scott, Mortimer, & Aguiar, 2006) focusing on content knowledge. A recent study found that there were differences in the concern whether or not pupils were learning depending on the teachers' level of expertise (Wolff, van den Bogert, Jarodzka, & Boshuizen, 2014). This study showed pre-service teachers to be more concerned about the pupils' behaviour and discipline.

RESEARCH QUESTION

In this study I have identified the following research question: How do teacher groups on four different stages of expertise – from pre-service to experienced – describe the skills, knowledge and competence needed in order to be a good physics teacher?

RESEARCH DESIGN AND METHODS

The research design used is guided by the interactive qualitative research design approach proposed by Maxwell (2013).

The study will be based on the conceptual framework of PCK (Shulman, 1986, 1987). PCK was first proposed by Shulman as an answer to what he and his colleagues referred to as 'the "missing paradigm" problem' (1986) where the different research paradigms for the study of teaching were missing the focus on subject matter. Further, Shulman pointed out that no one asked the question about "how the subject matter was transformed from the knowledge of the teacher into the content on instruction" (p. 6). This led Shulman (1987) to the following definition of PCK:

But the key to distinguishing the knowledge base of teaching lies at the intersection of content and pedagogy, in the capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by the students. (p. 15)

In this way PCK differentiates the teacher from disciplinary experts and colleagues who teach other subjects (Grangeat, 2015). In this study I will use the model that arose from the PCK Summit in 2012 (Berry, Friedrichsen, & Loughran, 2015) as described by Gess-Newsome (2015). She places PCK as part of a broader theoretical model referred to as teacher professional knowledge and skill (TPK&S) and adds skill to PCK: PCK&S. In this model PCK&S consists of personal knowledge, skill and enactment. In this study, the focus is on the skills, knowledge and competence that teacher groups on various stages consider central for being a good physics teacher.

In this study I use a short questionnaire with two slightly different versions, one for pre-service science teachers and one for in-service physics teachers. The teacher students only answer one question: *What kind of knowledge do you need to be a good science teacher?* The question is asked in Norwegian and is hard to translate directly because of a Norwegian word that is peculiar to Norwegian, "kunne", which may incorporate both knowledge and skills. Thus, the question may be best translated into knowledge in terms of TPK&S. The physics teachers will answer two questions: *Have you been teaching physics for more than three years*? And, *what kind of knowledge do you need to be a good physics teacher*? The choice of defining experienced teachers as those who have been teaching physics for more than three years was based on the review by Kagan (1992).

The first-year science teacher students will be asked to answer the questionnaire on paper during the first week when entering the programme. Final-year science teacher students will be invited by e-mail to respond to the questionnaire digitally. All Norwegian universities offering 5-year integrated masters' programmes leading to a science teacher qualification for lower and upper secondary school will be invited to collect data among their students. The physics teachers will be invited to the questionnaire through an e-mailing list for physics teachers in Norway and a closed Facebook group only for physics teachers. Their answers will be collected digitally. The Norwegian Social Science Data Services (NSD) has been notified about this study to secure the handling of personal data of the participants.

A pilot study among physics teachers attending a three-day in-service course, and the first data collection among first-year teacher students in science were made during the autumn of 2015. More data from in-service teachers and final-year teacher students will be collected during the spring 2016. Additionally, in August 2016, more data from first-year students will be gathered. A summary of the plan for data collection is given in Table 1.

Participants	*Specialised in a discipline*	*Questionnaire with one or 2 questions*	*Questionnaire format*	*Data collection*
1st year pre-service teachers	*No*	*1*	*Paper*	*August 2015 August 2016*
Final-year pre-service teachers	*Yes*	*1*	*Digital*	*Spring 2016*
In-service teachers pilot	*Yes*	*2*	*Paper*	*November 2015*
In-service teachers ≤ 3 years experience	*Yes*	*2*	*Digital*	*Spring 2016*
In-service teachers > 3 years experience	*Yes*	*2*	*Digital*	*Spring 2016*

Table 1: Summary of participants and data collection procedures

The data collected will be analysed using thematic coding (Braun & Clarke, 2006) mainly with an inductive approach, but with a view to the components described as part of TPK&S.

PRELIMINARY FINDINGS

In the first data sample among first-year students at the University of Oslo, 58 out of 60 students present did answer. Most of the students answer that disciplinary knowledge is important knowledge to be a good science teacher. Several students also emphasise the importance of being able to interact with other people. As an example, one of the students answered: "To know your subject well, but even more important is to be a good pedagogue. Having a lot of knowledge is not important to a teacher if you are not able to communicate the knowledge". This answer is interesting because the teacher student implies that communication strategies are important. Other teacher students expressed the importance of seeing students as individuals. Only a few mentioned discipline and behavioural norms as important, which might conflict with the main findings of Wolff et al. (2014). With more data, especially with data from final-year students, this preliminary finding will be explored in more detail. The pilot data findings from the in-service teachers indicate more focus on the bridging between pedagogical knowledge and content knowledge, and also the importance of having a dialogic approach (Scott et al., 2006) as the following excerpt illustrates: “You must feel comfortable when discussing [with the students] students’ conceptions about physics phenomena, and not be knocked off your perch if you are not able to come up with a ‘key answer’.” This is in accordance with the findings of Angell et al. (2005).

This study will be useful to improve pre-service science teacher education and support for novice physics teachers. Particularly, discussion of the knowledge and skills required of an experienced physics teacher may help novices to direct their attention towards the intersection of pedagogy and content. Moreover, the study will serve as a useful background for studying how an educational design research project like ReleQuant may contribute to developing the professional knowledge of teacher students and physics teachers involved in the project.

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DIALOGIC ARGUMENTATION AND PHYSICS LEARNING IN LOWER SECONDARY CLASSROOMS

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OUTLINE

In my PhD project I examine dialogic argumentation in lower secondary physics education. I am especially interested in how students' argumentation skills change as a result of using specifically designed activities and purposeful teacher guidance. Additionally, I investigate how the use of student-centered, dialogic argumentation as a teaching strategy affects learning the content knowledge of physics. In this paper I will present a qualitative method for studying dialogic argumentation in physics education.

I refer to dialogic argumentation as a verbal process where the students examine the validity of a conclusion, model or prediction in the light of evidence and theory (Duschl & Osborne, 2002). In today's society argumentation skills are important concerning both the independency of the individual and rational public discussion (Osborne, Erduran, & Simon, 2004). The ability to form sound arguments and to evaluate the validity of presented arguments is vital as we are faced with a continuous news flow (Millar, Osborne, & Nott 1998) and sustained social media use. These skills are particularly important in scientific and technological issues where contrasting views cannot be labelled as differences of opinion (Millar et al., 1998; Osborne et al., 2004).

LITERATURE REVIEW

Dialogic argumentation is important for the co-construction of knowledge (Duschl & Osborne, 2002). As students interact and learn in cooperation by, for instance, taking part in argumentation, they are actively engaged in the learning process and have to apply higher-level thinking (Duschl & Osborne, 2002). Some studies have indicated that using argumentation as a learning strategy improves also the students' mastery of scientific content knowledge (Zohar & Nemet, 2002). Furthermore, as students engage in argumentation they voice their thinking, which enables formative assessment (Duschl & Osborne, 2002; Osborne et al., 2004).

Earlier studies on classroom argumentation have either been interventions with short professional development programs for teachers or teacher-students (e.g. Zohar & Nemet, 2002) or longer studies concentrating on presenting and categorising distinct features of the argumentative discourse or teacher guidance (e.g. Osborne et al., 2004; Simon, Erduran, & Osborne, 2006). My PhD study is part of a longitudinal research project on the interplay of the students' argumentation and the teacher's guidance systematically in both physics and mathematics classrooms (DARLING: Dialogic Argumentation for Learning).

Methodologically, we wanted to apply a comprehensive and cross-cutting coding system that combines the structural, content-related and dialogic aspects of argumentation into an informative ensemble. Weinberger and Fischer's method (2006) covers all these viewpoints, but has two problematic premises: firstly, Weinberger and Fischer's method is developed for complex computer-supported collaborative learning tasks with text typed by students as the raw data and, as far as we know, its applicability for analysing diversely intricate face-to-face discourse has not been confirmed. Secondly, Weinberger and Fischer's method is founded on Toulmin's Argument Pattern TAP (Toulmin, 1958), which we found very difficult to apply identically in both physics and mathematics classroom. Thus, we developed a simplified version of TAP for analysing the structure of the arguments, and built our methodology on that.

RESEARCH QUESTIONS

My PhD study will aim to answer two research questions:

1. How do the students' argumentation skills change over time as a result of continual use of specifically designed activities and purposeful teacher guidance?
2. How does the use of student-centered, dialogic argumentation as a teaching strategy affect the learning of the content knowledge of physics?

In the process of answering the above questions, I will develop and validate a method of qualitative analysis for studying argumentation in the classroom. On a practical level I will plan, compose and test several activities and approaches for using argumentation in physics education. The activities will include both conventional pen-and-paper as well as computer-supported tasks on easy-to-use, free platforms. All materials will be available for public use.

It should be noted that this paper presents qualitative methodology related to RQ 1; RQ2 will be examined with a mixed methods approach, which will utilise the qualitative methods presented here and quantitative tests developed later on in the study.

DESIGN AND METHODS

We will analyse the arguments in four dimensions. The analysis of the *structure of an argument* is a modified simplification of TAP. As a starting point, we wanted to concentrate on the general process of justifying one's claim. We are interested in whether the students simply provide unconnected *supports* for their *claims*, or if they actually apply conscious and thorough *reasoning.* We agree that explicit qualifiers and rebuttals, i.e. *considering uncertainty* related one's argument increase its plausibility (Erduran et al., 2004), so we wanted to include this category as well. Moreover, we are interested in whether the students present *counter claims*; this is an important structural category with respect to the dialogic aspects of argumentation.

There are two dimensions in our coding to cover the content of the arguments. The *basis of an argument* describes where the reasoning originates and how it progresses: *inductive, deductive* or *leaning on an external authority* (modified from Harel and Sowder, 1998). We also evaluate the *scientific accuracy of an argument* (modified from Zohar & Nemet, 2002) according to the student's existing knowledge as *accurate, partially accurate* or *false*.

Finally, we are interested in argumentation as part of the learning dialogue. In the prominent, sociocultural practice of education, learning and construction of knowledge are seen as language-mediated, social processes (Mortimer & Scott, 2003).

Thus we wanted to see how the argumentation progresses on the dialogical level: if and how students co-construct arguments and chains of reasoning. We chose a categorisation that is connected to Mortimer and Scott's (2003) well-known framework for the communicative approach in classroom interaction. The dialogic argumentation is approached from two perspectives: *the dialogic moves* that students make to persuade others of the validity of their arguments (e.g. *building off* or *critiquing each other's ideas*), and *discussing competing claims*, i.e. discussion of more than one plausible claim during the argumentation process (McNeill, Gonzaléz-Howard, Katsh-Singet, & Loper, 2016).

Currently we are conducting a pilot study at one lower secondary school in central Finland. We have documented four physics lessons where the teacher and students engage in argumentation by carrying out activities designed specifically by us. The pupils are eighth-graders, i.e. 14-year-olds. Each small group or pair of students and the teacher have a video camera with a microphone recording their activity and discussion. The videos will be analysed using ATLAS.ti – software by two different coders and Cohen's kappa will be calculated to confirm the reliability of the coding.

The study's longitudinal phase will start in the autumn of 2016 and go on for two academic years. Seven teachers' lessons in both physics and mathematics will be recorded about once a month, respectively. The students will be the same for each teacher on both subjects for the whole two years. The activities for the lessons will be designed in collaboration between the DARLING group and the teachers. This technique has been found very useful and effective by Simon et al. (2006).

PRELIMINARY FINDINGS

When analysing the structure of the students' arguments, we have seen that most students offer claims without support or reasoning. Moreover, giving a single support, i.e. an example or a fact, is more common than offering reasoning. However, a few students are capable of forming well-justified arguments with more than one rationale.

Most of the well-justified arguments are, at least partially, scientifically accurate: it seems that students are quite timid to voice their ideas if they don't have convincing grounds for them. The scientifically false or irrelevant rationale found in the data usually projects common misconceptions. In analysing the basis of the arguments we have seen that students mostly offer inductive rationale.

We have seen that students often build their claims, supports and reasoning off each other's ideas. Questioning and critiquing each other's ideas is also common. It should be noted that the two dimensions related to dialogical aspects of argumentation are not exclusive: there are examples with e.g. both questioning and discussion on competing claims. Otherwise, students quite easily grab onto the first idea they get and are satisfied with supporting it; discussing competing claims with proper reasoning has only been found a few times in the data so far.

The preliminary findings are in line with previous research on this topic. Indeed, we did not expect to make new discoveries at this point; only to test that our methodology works. I will continue working with the method and the pilot data through the summer and exhibit the validity of our method at the summer school.

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SYSTEMIZING AND EMPATHIZING: RESEARCH ON EARLY YEARS SCIENCE EDUCATION AND BRAIN TYPES

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OUTLINE: SCIENCE FOR ALL

An interesting approach for explaining differences in the motivation for science is the Empathizing-Systemizing (E-S)-Theory (cf. Baron-Cohen, 2002). It says that every person has a so called "brain type". People who have the brain type "systemizer" are generally more engaged in science and motivated to do science than people who are stronger in empathizing (Zeyer, 2013). But, if we want a "science for all" (Aikenhead, 2001, p. 4) and not a "swing away from science" (Zeyer, 2013, p. 1047), we have to motivate also empathizers for science. How to realize that?

Main goal of the study is to go the first step and find out how pre-school children with different brain types act and react in differently structured learning environments on the same topic. Respectively, we are observing tested children within two different learning environments in order to investigate potential different behavior. Thus, our main research question is: What are the reactions empathizing and systemizing pre-school children show to different teaching approaches?

Three steps organize our approach: In a first step, the brain types of 4 to 6 year old pre-school children were determined using a 55-item EQ-SQ-questionnaire for parents (cf. Auyeung et al., 2009) that we translated into German. In terms of a design-based research approach (cf. Collective, 2003), the tested children then are observed while acting within two different scientific learning environments. In year 2015 we started the first one with a more structured approach, in 2016 the more open one follows. The videotapes are analyzed using a category-based system with focus on the children's attention.

SHORT REVIEW OF RELEVANT LITERATURE

According to the E-S-Theory, individual's brains should correlate to a type between two dimensions: the empathizing and the systemizing. "Systemizing is the drive to analyze or construct systems" (Baron-Cohen, 2009, p. 71) mainly with the intention "to identify rules that determine a system" (Zeyer et al., 2013, p. 1048) and to "predict how that system will behave" (Baron-Cohen, 2009, p. 71). "Empathizing is the drive to identify another person's emotions and thoughts and to respond to these with an appropriate emotion" (Auyeung et al., 2009, p.1). In the majority of cases people shift between the two dimensions (Baron-Cohen, 2009, p. 72). Billington et al. (2007) found that the brain type seems to be a better predictor than gender, concerning the individual motivation to study science. Through an empirical cross-cultural study, Zeyer et al. (2013) added the finding that only systemizing has an impact on motivation to study science.

From that, Zeyer et al. (2012) concluded that people with an empathizing or a systemizing cognitive style need different approaches to science because, due to their brain types, they are not similarly motivated in this field of education. In order to motivate empathizing children for science they suggest to re-organize the lessons or the learning environments. They recommend first-person-perspectives and context-based-approaches (Zeyer, 2013, p. 1062).

EARLY YEARS SCIENCE AND MOTIVATION

At the common practice, different approaches to elementary science are existing. Seeing the child as “protagonist of its own development”, while adopting its knowledge like a scientist by “being self-actuating”, is one of the approaches (Schäfer 2011, p. 27). Fthenakis (2009) sees the child as an active part of its own educational process in co-construction with others. Lück (2003) proposes children to construct their new knowledge – e.g. in a pre-structured series of experiments and a subsequent interpretation. According to Zeyer et al (2013), we assume that fictions and the identification with protagonists should better motivate empathizers to do science. These different approaches will guide us for the design of two different types of learning environments.

RESEARCH QUESTIONS – STEP 1

Knowing that motivation is an internal condition that elicits, leads and maintains the children’s behavior (Glynn & Koballa, 2006, p. 25) we aim on analyzing observable behavior. In addition, we also know that “Motivation cannot be observed directly” (Barth, 2010, p. 107 ff.). For that, we decided to use the “Leuven Scale of Active Engagement in Learning” (cf. Laevers, 2007). With this, Laevers specified different signs of motivation. These are bodily posture, attentiveness, endurance, accuracy, responsiveness and contentment. In the first step of our analyses, we will focus on the attentiveness we can observe. If we assume that someone is motivated when he or she follows attentively in a situation, the children’s attention should be lower in learning environments that are not according to their brain type.

At first, the children participate a more structured and strongly guided setting. So our specific research question is: Do the empathizing and systemizing children show different behavior concerning their attentiveness in a more structured learning environment?

Afterwards, we will try to answer the same question for a learning environment, that starts with an introduction of a story (identification with protagonists) and lets the kids start to investigate by themselves.

RESEARCH DESIGN AND METHODS

Applying the questionnaire, Baron-Cohen et al. (2009) identified five different brain types: Extreme Empathizer (EE), Empathizer €, Balanced, Systemizer (S) und Extreme Systemizer (ES). The questionnaire he used, was adapted and validated by Auyeung et al. (2009) for 4 to 11 year old children. Just like adults, children could be allocated to brain types.

In a first step, we translated this “EQ-SQ-Child questionnaire” into German language and applied it to the parents of 59 pre-school children in 2015. Based on the E-S-Theory, we developed a strongly guided learning environment on the topic “absorption” for pre-school children.

Then, mixed groups of about four pre-school children have been participating in this first approach. Guided through questions and hints given by an elementary teacher sitting at a table with them, they had to investigate different materials concerning their ability of absorption. They had to find out the best and the worst absorbers, and to explain why the different materials react differently to water. During the activity, the children's behavior has been video-recorded using two camcorders looking from different perspectives.

The videotapes are the basis for our empirical analysis (Mayring, 2008). We developed inductively categories with the focus on the children's viewing direction. A more qualitative analysis concerning the quality of the children's actions just started.

PRELIMINARY FINDINGS: THE EQ-SQ-QUESTIONNAIRE

By now, the first 59 children of the population have been investigated. The internal consistency of the results has been tested for the questionnaire data. Cronbach's alpha coefficients were calculated und showed high coefficients for empathy items (α=0.81) as well as for systemizing items (α=0.61). Within this group we found a normal distribution: 2 EE, 18 E, 17 B, 20 S and 2 ES. This result is in accordance to the literature data of Auyeung (2009). Thus, we can conclude that the translated questionnaire should be valid and reliable.

In comparison with the distribution of values in the original study of Auyeung, the results show also that the extreme values (EE=Extreme Empathizer und ES=Extreme Systemizer) were not acquired in our Study I.

PRELIMINARY FINDINGS: VIDEO ANALYSES

The two videotapes of each setting were inset in the evaluation software program „Videograph" (Rimmele, 2012) und synchronized. Inductively we developed eight observation categories with the focus on the children's viewing directions: "Towards Preschool Teacher, Towards other Children, At the Experimentation Material, Towards the Observer/into the Camera, Around, Material, that is not relevant right now, Indistinguishable, Any other business". In the following step, we decided to summarize the fourth, fifth and sixth code to the new category "Distraction/ Attentiveness".

After the evaluation of the videotapes with the focus on the children's viewing directions, we compared the two children with the extreme brain types (child 111= EE and child 49=ES). Looking at the direct relation, it was seen that there are differences in the duration time of viewing in different directions. The extreme empathizing child looks 0,94 % of the time at other children. On the contrary, the extreme systemizing child looks at this direction 6,21 % of the whole time. However, the new code "Distraction/Attentiveness" shows a difference in the viewing times (child 11=6,24% and child 49=8,55%). This does not meet our hypothesis, that the empathizing child should be longer distracted than the systemizing child in the more structured setting. At this point, more data and deeper analyses have been started in order to clarify the results. We just started with a comparative description of the children's activities.

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DEVELOPMENT AND VALIDATION OF A LEARNING PROGRESSION OF BASIC ASTRONOMY PHENOMENA

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INTRODUCTION

Learning progressions (LP) have been recently proposed as a key research approach to describe and interpret students' understanding of core concepts in science. There is an increasing consensus in the science education community on the pivoting role of validated LPs, since they can be useful means to improve teaching practices at different school levels. In this research project we plan to develop and validate a LP that ties together three basic astronomical phenomena: change of seasons, solar and lunar eclipses and Moon phases. This choice is justified by the fact that astronomy topics can motivate and attract students, stimulating their sense of discovery. Moreover, previous research studies have shown that students hold a variety of misconceptions about basic astronomical phenomena.

REVIEW OF LITERATURE

Curricular reform documents define LPs as *"descriptions of the successively more sophisticated ways of thinking about a topic that can follow one another as children learn about and investigate a topic over a broad span of time"* (NRC, 2007). On such basis, previous studies in science education adopted the LP framework to describe and interpret how students develop their understanding of a given concept across school levels (Duncan & Hmelo-Silver, 2009; Duschl, Schweingruber & Shouse, 2007; Stevens, Delgado & Krajcik, 2010). LPs are rooted in a developmental view of learning (Driver, 1994) in which the students learn a given science content starting from their intuitive ideas (*lower anchor*) and progress through subsequent levels of more sophisticated understanding of the topic towards the scientifically correct idea (*upper anchor)*. The process of validating a LP is a research-based cycle (Neumann, Viering, Boone & Fischer, 2013). After an initial LP has been developed, further data are collected to inspect the alignment with the actual students' achievements. If the alignment is poor, the measurement instrument and the initial LP need to be revised. In doing so, empirical evidence about the different levels of conceptual understanding is collected and used to tune the initial LP with the instrument. The cycle ends when alignment between actual and hypothesized outcomes becomes sufficiently satisfactory. In this research project, we will develop a LP about basic astronomy phenomena - change of seasons, lunar and solar eclipses and Moon phases – which research has proved to be difficult to understand for the students. For instance, students think that seasons are caused by the changing distance between Sun and the Earth (Baxter, 1989). In other cases, students do not take into account in their explanations of all the conditions for the change of seasons: for instance, often they do not refer to the tilt and the constant direction in space of Earth axis (Atwood & Atwood, 1996). As far as Moon phases and solar/lunar eclipses, students often confuse the two phenomena (Trumper, 2001) or explain them only in terms of the shadows of other planets (Baxter, 1989). Willard & Roseman (2007), Sneider, Bar & Cavanagh (2011), Plummer & Maynard (2014) have developed LPs about astronomical phenomena and causes of seasons. However, the LPs developed in these studies are focused separately on the three phenomena and have been validated only across middle school level (11-13 years). Our aim is to extend such previous research studies by developing a single LP for the three phenomena targeting students' progression of understanding from the beginning of middle school to graduate level.

RESEARCH QUESTIONS

This project study will be guided by the following research questions:

- RQ1: how do students develop their understanding about change of seasons, Moon phases and solar/lunar eclipses from middle school to graduate level?
- RQ2: drawing on RQ1 findings, which learning progression that describes students' cognitive levels about the addressed astronomical phenomena can be hypothesized?
- RQ3: how well does the hypothesized learning progression actually describe students' understanding of the addressed astronomical phenomena across different educational levels? How can it be optimized?
- RQ4: to what extent a teaching- learning sequence based on the optimized learning progression is effective in addressing students' misconceptions about the addressed astronomical phenomena?

RESEARCH DESIGN

To answer RQ1, we have initially developed an open questionnaire, based on previous studies, submitted to 189 students at the beginning (13-14 years old) and the end (18-19 years) of the secondary school course, and to undergraduate astrophysicists students at the University (about 10). Starting from the open questionnaire results, we have developed a first version of a LP for each phenomenon (RQ2), identifying a suitable number of levels (around 2-3) of increasing sophisticated explanations. Upper and lower anchors of each LP were defined starting from the collected data (see methods section). To empirically validate the hypothesized LPs (RQ3), a 48-items mixed true/false, multiple-choice questionnaire was developed. The items were designed and grouped so to correspond to the LPs levels. Two versions of the questionnaire were developed, one for the middle school level, the other for secondary school and graduate students. Emerging patterns of students' answers to the questionnaire will provide support for designing a single leaning progression about Celestial Motion in which the three phenomena are interpreted and described in a more coherent way (see methods section). Finally, drawing on RQ3 results, we will develop suitable teaching-learning sequences (TLSs) for the targeted levels of instruction (middle and secondary school). The TLSs will help student progress across the subsequent levels of the resulting LP about Celestial Motion (Psillos & Papadouris, 2016). Finally, the TLSs will be validated (RQ4) through cycles of school implementation during which further data (field observations, students' worksheets) will be collected.

METHODS

Students' answers to the open questionnaire were analyzed through a content-based iterative categorization: levels of understanding were coded as informed, partial and naïve. The emerging categories informed initial LP levels. In particular, naïve answers were used to define the lower anchor of the LP, while partial and informed answers were used for subsequent levels. Students' answers to the mixed true/false multiple-choice questionnaire were analyzed using Rasch analysis. Rasch analysis relates the probability of correctly answering an item to the difference between a student's ability and an item's difficulty. Results are usually in form of a Wright map, in which students' abilities and items' difficulties are presented together. By using Rasch analysis, it was possible to lump together the two different forms of the questionnaire. Moreover, given the adopted design of the questionnaire's items, comparing difficulties of the items hence allowed us to compare also levels of the hypothesized learning progression and to revise them according to actual students' achievements. The single learning progression about the three phenomena will be developed by grouping items by their difficulties, as emerged from the Rasch analysis. Finally, to validate the developed TLSs we will use as pre- and post-test the two versions of the questionnaire and we will triangulate results with evidences emerging from the other data sources.

PRELIMINARY FINDINGS

At this stage, we have analyzed secondary and graduate students' answers to the open and to the mixed true/false multiple-choice questionnaire. Results show that the average percentage of correct answers for students at the end of secondary school does not exceed 60%. Concerning differences among the three phenomena, we note that questions about Moon phases were the most difficult, while the lowest average score of the fifth class students concerned questions about eclipses. The initial hypothesized LPs were thus only partially supported by data. The revised version seems to better describe progression of students' understanding from secondary school to graduate level. Further data analysis will be carried to investigate alignment of the revised LP with middle school students' achievements. In parallel, TLSs are being developed.

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INVESTIGATING ITALIAN SCIENCE TEACHERS WHILE IMPLEMENTING TEACHING LEARNING SEQUENCES

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INTRODUCTION

Scientific Inquiry (SI) is nowadays considered an essential component of scientific literacy (Lederman & Antink, 2014). Inquiry approaches allow students to experience science in a way that is grounded in real contexts (Jenkins & Nelson, 2005). In such approaches, methods of inquiry used by students resemble the way in which professional scientists and researchers carry out their work (Blanchard et al., 2009). In particular, inquiry approaches can take different forms, which reflect the different procedures followed by scientists to formulate and test their hypotheses (Knorr-Cetina, 1999). Teaching resources, aimed to implement inquiry in classroom practice, are available since long time (Singer, Marx, Krajcik & Chambers, 2000). However, teachers' interactions with didactic materials are mediated by their knowledge, ideas and beliefs. Moreover, teachers may be convinced to actually implement SI even if their knowledge about SI is only vague (Capps, Shemwell & Young, 2016). Similarly, previous studies have shown that when implementing innovative teaching-learning approaches, even trained teachers can "transform" the original designers' objectives (Giberti et al., 2001). The term "transformation" refers to how innovative resources and approaches are selected and reorganized by the teachers that adopt them (Pintò et al., 2003). While some transforming trends may lead to fruitful modifications, others may impact in a negative way, leading, in some cases, to what Brown and Campione (1996) call a *lethal mutation*in the enactment of curriculum materials, namely an adaptation of the approach that deviates substantially from the designers' aims. Teachers' transformations of inquiry approaches may justify the contradictory research evidence about the effectiveness of such an approach (Minner, Levy & Century, 2010). However, much less is known about what are the specific aspects of inquiry that are more likely to be transformed by teachers.

For such reason, this Ph.D. research study will concern the analysis of Italian secondary school teachers' transformations when implementing inquiry-based approaches in school practice. The specific research question that will guide the study is: *which are the aspects of inquiry that teachers mostly accept/transform in their school practice?*

THEORETICAL FRAMEWORK

To study teachers' transformations, we adopted a modified ARI (Adaption and Re-Invention) Model (Rogers, 1983), useful to describe how a teaching-learning sequence (TLS, Méheut & Psillos, 2004), developed for a certain educational context, is implemented in a different one. The framework works as follows: first, "core" and "not core" elements of a given TLS are identified. *"Core"* elements are those essential features of IBSE teaching which should not be changed while implementing a TLS, since they characterize it in a unique way. Core elements are exemplified by actions that the teacher and students carry out during the activities. *"Non core"* elements are complementary features that mainly concern classroom management (Harris and Rooks, 2010), and can be changed to better fit the TLS in school practice. Then, after classroom implementations, the TLS, as enacted in teacher's practice, is compared with the original one to identify aspects that have been adopted/ transformed.

RESEARCH DESIGN

The research project is structured in three iterative phases: (i) involvement of ten science teachers in a professional development (PD) course (about 30 hs) aimed at developing teachers' pedagogical content knowledge about scientific inquiry; (ii) implementation on behalf of each teacher of an inquiry-based module in classroom (about 5 hours); (iii) feedback on classroom activities using video-based analysis of the activities. In the first phase, existing research-based TLSs[9], already validated in different educational contexts, are presented to teachers. Overall, all TLS concern specific science contents featured in the Italian secondary school curricula and share common meta-cognitive objectives related to the nature of SI. In the second phase, the teachers implement in their classroom one/two TLSs among those proposed. In this phase, enough freedom is given to teachers in order to adapt the proposed activities of the modules to their needs and specific school context. Audios and videos are collected to observe significant students' reactions to teacher's specific triggers. In the third phase, data collected by the external observers are analysed, to evaluate what are the SI aspects adopted/transformed by teachers.

METHODS

To analyze collected data, the implementation of the TLS will be subdivided into equal periods of ten minutes each. Then, an iterative categorization process of significant teachers' actions during each period of the implemented TLS will be carried out by two independent researchers. Teachers' actions here are defined as teacher-student interactions, in particular, the extent to which the teacher involves students in SI features (e.g. generating research questions, reflect upon experimental results). Among the categories emerged, only those whose indicators will occur at least twice in each period of the TLS will be selected and uniquely assigned, according to the ARI model, to Core/Not core aspects of the TLS. To provide evidence about what have been the aspects mostly accepted / transformed by each teacher, the categories will be scored according to the extent to which it is descriptive of what happened in classroom in the specific period: *low* if the category does not accurately describe teacher's actions; *medium* if the category partially describe teacher's actions, *high* if the category fully describes teacher's actions. The final score for each category will be calculated by averaging scores on all time frames. To investigate whether a specific aspect is transformed across the sample, a numerical parameter, Δwill be introduced. This parameter indicates the difference between teachers with a score = 3 and teachers with a score less or equal 2 in that aspect, namely between teachers who did not transform that aspect and teachers who partially or fully transformed it. Hence, depending on the calculated value, each category will be labelled as: *heavily transformed*, if $-9 \leq \Delta \leq -3$; *somewhat transformed*, if $-1 \leq \Delta \leq +1$; *adopted*. if $+3 \leq \Delta \leq +9$. Finally, for each teacher, an overall score for Core and Not core aspects will be obtained by averaging the scores of each corresponding category. We will use a three-level variable, to evaluate

[9] Sheffield Hallam University (SHU, 2009) *Earth and Universe Project Research Briefs*. On-Line, retrieved 11-08-2014, www.chreact.eu

degree of transformation enacted by each teacher: *heavy transformations*, Score < 2 (majority of lows), *some transformations*, 2 ≤ Score ≤ 2,5 (majority of mediums), *almost no transformations*, Score > 2,5 (majority of highs).

PRELIMINARY FINDINGS

Among the twenty teachers involved in the first two PD courses during academic years 2013/2014 and 2014/2015, thirteen were selected (9 female, 4 male; students involved of about 14-16 years old). Analysis of videos and audios collected in this first phase (60 h; thirty frames of ten minutes per teacher) has led to the adoption of nineteen categories, assigned according to the ARI model to Core and Not core. For categories scoring, a final negotiation between the raters led to a consensual agreement with an inter-rater reliability Kappa value of 0.76. Preliminary findings suggest that teachers were overall more resonant in Not core than in Core aspects of the implemented TLSs. The most striking result is that the majority of the core aspects have been only partially adopted or completely transformed by the sample, leading teachers to do *heavy transformations* in these aspects. Plausible reasons for the obtained evidence will be investigated and discussed in more details during the Ph.D. course, comparing the results obtained with those we will collect in the next years of research.

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DEVELOPMENT AND EVALUATION OF THE HANDS-ON PARTICLE PHYSICS LEARNING LABORATORY S'COOL LAB AT CERN: ROLE OF STUDENT AND LABORATORY CHARACTERISTICS IN CONCEPTUAL LEARNING AND SATISFACTION

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INTRODUCTION

S'Cool LAB is an international out-of-school hands-on learning laboratory for high-school students at CERN, Geneva, Switzerland (S'Cool LAB Website, 2015). During workshops in S'Cool LAB, students (age group 16-19 years) work with high-tech equipment to independently perform modern physics experiments that are linked to CERN's technologies and physics. By doing so, students gain insight into the fundamental principles of physics used at the world's largest particle physics laboratory. S'Cool LAB's aim is to make CERN's scientific programme understandable to students through hands-on experimentation. Volunteering CERN scientists facilitate workshops and guide the students. Particle detection, particle acceleration, and basic principles of modern physics as well as applications of particle physics are the main topics of S'Cool LAB workshops. These topics are not part of the standard high-school physics curriculum (Mullis, et al., 2012). Hacker and Hilscher (2009) argue that one of the main difficulties in teaching particle physics to high-school students is the lack of appropriate classroom experiments in schools. Well-equipped out-of-school learning places like S'Cool LAB can close this gap and provide real experiences with particle physics measurements. However, every out-of-school learning place should not only consider the possibilities of modern equipment when designing learning activities but also take into account knowledge of the audience's conceptions of the topic to be presented, because education research suggests that learners' conceptions influence how information is interpreted (Henriksen & Jorde, 2001). Therefore, the design process of learning activities in S'Cool LAB is approached from a constructivist viewpoint. Students' conceptions are studied and taken into account when designing learning activities, which allows students to actively construct new knowledge (Duit, 1996). Therefore, Prediction-Observation-Explanation (POE) tasks (White & Gunstone, 1992) based on documented students' conceptions are an integral part of experimental activities in S'Cool LAB with the goal to a) assess and study students' conceptions, to b) evaluate and improve the hands-on learning activities in S'Cool LAB, and to c) foster learning. Experiences from POE tasks are used to construct concept test questions to measure students' learning gain throughout the workshops. To evaluate which factors are essential for learning in S'Cool LAB, regression analysis methods are used to explore the relationship between learning gain and student characteristics such as physics related self-concept, interest and engagement, and curiosity as well as laboratory characteristics such as cognitive load, deep level activation, tutor support, and perceived novelty. Additionally, the potential impact of S'Cool LAB workshops on students' interest and engagement, self-concept and curiosity is studied.

LITERATURE REVIEW

Hands-on Out-of-school Laboratories

The common goal of out-of-school laboratories is to provide a place for independent experimentation and research for students. Mostly, they are affiliated with universities, associations, research centers, museums or science centers and are characterized by modern science and technology topics, state-of-the-art laboratory equipment, regular activities for students, unique and authentic learning opportunities, and personal contact with scientists (Streller, 2015).

Conceptual Learning with Experiments

Although experiments are commonly perceived as key component of science teaching in high school and university, Bates (1978) among others questioned the effectiveness and the role of laboratory work. Previous studies have shown that only laboratory experiences which include metacognitive learning experiences like POE tasks or Peer Instruction (Mazur, 1997) significantly improve conceptual understanding (Miller, Lasry, Chu, & Mazur, 2013). Therefore, POE tasks are an integral part of learning activities in S'Cool LAB.

Students' Conceptions about Modern Physics Experiments in S'Cool LAB

Currently, three different experiments are used in S'Cool LAB workshops: cloud chambers, electron tubes, and X-ray machines. Do-it-yourself cloud chamber based on dry ice and isopropanol are build by students to study cosmic particles and particles from natural terrestrial radiation sources. So far there has been only very little research on students' conceptions about this topic. Portuguese high-school and university students showed very little awareness of cosmic particles and terrestrial sources of ionizing radiation compared to other radiation sources in a study by Rego and Peralta (2006).

In cathode ray tubes (or electron tubes) students study the behaviour of electrons in electric and magnetic fields. Previous studies found that students have problems differentiating between the effects of electric and magnetic fields on electrically charged particles (Maloney, 1985), (Scaife & Heckler, 2011). Many students believe, for example, that the poles of a magnet are electrically charged and attract or repel electrically charged particles (Maloney, O'Kuma, Hieggelke, & Van Heuvelen, 2001). Previous concept tests about electromagnetism (e.g. by Maloney, O'Kuma, Hieggelke, & Van Heuvelen (2001)) have been used and validated among university students and lack adaptation for high-school level.

X-ray machines in combination with pixel detectors are used to study applications of particle physics in medical imaging. Previous studies reported various students' conceptions about ionizing radiation; for example, many students believe that after irradiation with X-radiation, objects become radioactive themselves (Eijkelhof, Klaassen, Lijnse, & Scholte, 1990). Furthermore, students seem to apply matter-like properties to radiation. In addition, students tend to assume that X-radiation has the same properties as visible light regarding reflection (Riesch & Westphal, 1975) and permeation (Clément & Fisseux, 1999). So far there is no validated concept test available for ionizing radiation although various aspects have been studied in paper-and-pencil tests with high-school students, e.g. by Eijkelhof (1990). To measure conceptual learning in S'Cool LAB with regard to the performed experiments and fundamental principles of particle physics, the main focus of this project is to develop and validate an appropriate concept test based on documented students' conceptions.

RESEARCH QUESTIONS (RQS)

Area of research 1: Evaluation of S'Cool LAB

- RQ 1.1: How do students like S'Cool LAB?
- RQ 1.2: Which role do student characteristics play in student satisfaction?
- RQ 1.3: Which role do laboratory characteristics play in student satisfaction?
- RQ 1.4: Has S'Cool LAB the potential to increase students' curiosity?
- RQ 1.5: Has S'Cool LAB the potential to increase students' motivation?

Area of research 2: Conceptual Learning in S'Cool LAB

- RQ 2.1: Which conceptions about the experiments in S'Cool LAB do students hold?
- RQ 2.2: Can workshops in S'Cool LAB improve conceptual understanding?
- RQ 2.3: Which role do student characteristics play in conceptual learning?
- RQ 2.4: Which role do laboratory characteristics play in conceptual learning?

RESEARCH DESIGN AND METHODS

Approximately 30 students from all over Europe visit S'Cool LAB per week and perform the experiments described above. A sample size of 1000 high-school students (age group 16-19 years) is expected at the end of the year 2016. Students fill out a pre-visit questionnaire approximately one week before their visit and a post-visit questionnaire approximately one week after. RQ 1.1 will be studied using a validated questionnaire about satisfaction with out-of-school learning places (Rennie, 1994). Regression analysis methods will be used to answer RQ 1.2, 1.3, 2.3 & 2.4. To answer RQ 1.4, 1.5 & 2.2, ANCOVA will be used to compare pre-visit and post-visit questionnaire results. RQ 2.1 will be answered by qualitatively analysing POE tasks and by student interviews during workshops.

PRELIMINARY FINDINGS AND DISCUSSION

During the development phase of learning activities in S'Cool LAB (Jun - Nov 2015) an iterative re-design process took place. POE tasks have been established to cognitively activate all students and to improve learning. The analysis of the POE prediction steps show that students in S'Cool LAB hold the same students' conception as reported by previous studies. The analysis of the observation steps shows that worksheets and guidance by tutors does not guarantee that students observe the outcome of an experiment correctly. Therefore another re-design step was necessary to improve student activities. In the explanation step students become aware of their conflicting conceptions and partially change their reasoning towards scientifically accepted conceptions. In spring 2016, student questionnaires and concept test questions will be piloted to allow continuous data taking after summer.

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PHYSICAL AND MATHEMATICAL MODELLING COMPETENCE AS PREDICTOR FOR SUCCESS IN PHYSICS DEGREE COURSES

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FOCUS OF THE STUDY

In order to account for the high number of physics students who drop-out (36%) and change course (26%) (Heublein, Schmelzer, Sommer, & Wank, 2008) at German universities, it is aimed at describing the success in physics degree courses by means of subject-related, psychological and demographic variables.

Our study, funded by the German Research Community (DFG), is part of the ALSTER project which investigates academic learning and student's success in degree courses in science and engineering in the first year of university. In ALSTER, success in studies is defined as remaining enrolled in the course and additionally measured by the gain in (physics) knowledge and by the exam grades of the courses.

THEORETICAL FRAMEWORK

In order to successfully study physics, students have to acquire physical and basic mathematical competences at the beginning of their course already, e.g. in basic physics lectures, i.e. mechanics and electrodynamics. Despite mathematics being taught as a stand-alone subject in a physics course, it is also part of the basic physics lectures with physics-characteristic traits. The extraordinary role of mathematics in physics becomes obvious when Prediger (2009) talks of mathematics as means of describing the world. Mathematics is also fundamental to the physical method and essential to gaining physical knowledge (Uhden, Karam, Pietrocola & Pospiech, 2011; Hitchin, 2007). For this reason we assume that the relationship between mathematics and the basic lectures in physics is a vital variable to describe the success in physics studies. Recent works have either investigated the prerequisites in the first year of physics courses looking at mathematical and physical contents separately (Buschhüter & Borowski, 2014) or have solely taken A-level grades and prior physics knowledge as predictors for the success in physics studies (Sorge, Neumann & Petersen, in press). In this study however, we aim at describing the relationship between mathematics and physics in such a way that understanding "physical description of a phenomenon involves learning to simultaneously apply and translate between various representations" (Angell, Kind, Henriksen & Guttersrud, 2008), i.e. students are successful if they manage to transform physical models into mathematical models, and mathematical models into mathematical results and to interpret these results physically which is called mathematical modelling (Borromeo-Ferri, Grünewald & Kaiser, 2013). The most prominent German modelling cycle in mathematics by Blum (2007) similarly defines modelling competence as being able to execute steps in a modelling process adequately and to analyze and to compare given models.

Trump (in press) replaces and specifies the term 'rest of the world' (Blum, 2007; Pollak, 1979), which is everything except mathematics, with physical contents as initial and final point in her modelling cycle. Thus, a model on physical-mathematical modelling results which fully meets Blum's requirements on mathematical modelling on the one hand and can additionally be used in the context of physics (education) on the other hand.

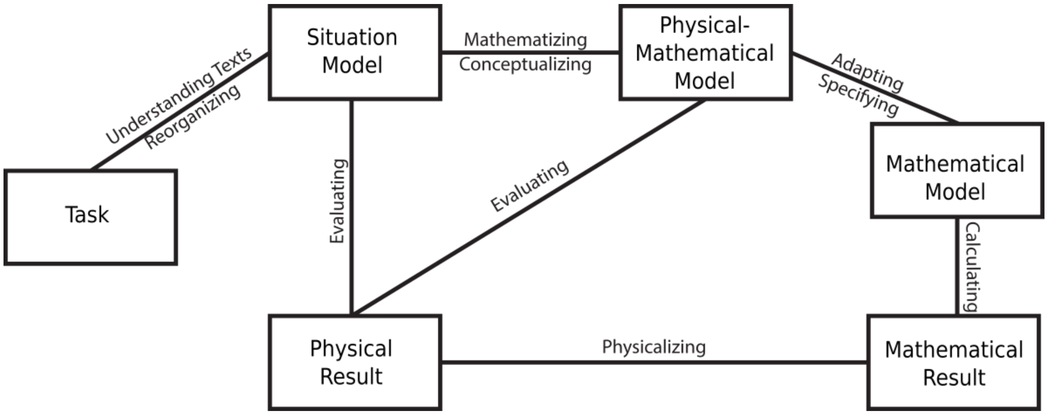

Figure 5: Physical-Mathematical Modelling Cycle adopted from Trump (in press)

The proposed physical-mathematical modelling competence, illustrated in *figure 1,* is the basis for the following **research questions:**

- **1** Is there a relation between physical-mathematical modelling competence in solving physics tasks and success in physics studies in the first year at university?
- **2.1** Is there an influence of prior (content) knowledge on success in studies?
- **2.2** Is there a relation between physical-mathematical modelling competence and prior (content) knowledge?
- **3.1** Is there an influence of the mathematical ability on the success in studies?
- **3.2** Is there a relation between physical-mathematical modelling competence and mathematical ability?

Further, we obtain additional data from the ALSTER project to what extend the ability to model physically and mathematically is related to extracurricular variables, e.g. school grades, and psychological variables, e.g. knowledge on metacognition, knowledge about learning strategies, the academic self-concept, general motivation to learn and study, expectations regarding the course and subject-related interest.

OUTLINE OF THE RESEARCH DESIGN AND METHODS

The sample is expected to be N=180 and includes students of physics at the universities of Duisburg-Essen and Bochum in the first year of their studies. We operationalize the competences mentioned above by employing subject-related, psychological and demographic tests in a longitudinal design at three different stages, namely before the start the physics degree course (10/2016), half a year into the course (02/2017) and at the end of first year (07/2017). This requires the design of three tests in my project; first a test on content knowledge, second a test on physical-mathematical modelling competence and third a test on mathematical ability. The test on modelling competence encompasses items on selected steps according to the adopted modelling cycle (*figure 1*). An analysis of lecture material and curricula of the basic physics lectures hints at a minimum of three different dimensions within the modelling competence which are considered in the test design.

PRELIMINARY FINDINGS

Test / University	content knowledge	modelling competence	mathematical ability
Aachen	*NA*	N = 172	N =172
Bochum	N = 23	N = 23	N = 23
Duisburg-Essen	N = 46	N = 46	N = 46
Potsdam	N = 79	N = 79	*pending*

Table 1: Numbers of participants of the first measurement in the pilot study

At this stage of our study we have only obtained the first sets of data from the pilot study conducted at four different universities across Germany simulating the first point of measurement. The second and third measurements of the pilot study are due by the end of 07/2016.

The first three universities in *table 1* are all in the federal state NRW which suggests that a combined analysis of the sets of data is legitimate to some extent. Physics students in Potsdam have not the same high school background since school curricula vary from one federal state to another. I calculated two Rasch analyses using the combined NRW sample for the content knowledge test and the modelling competence test, which yielded the results in *table 2*, and one Rasch analysis for the Aachen mathematical ability test (Persons per Item: 170 – 172, Number of Items: 38, EAP Reliability: 0.878, Variance: 1.073). A more detailed analysis of the still incomplete data is imminent.

Test / Statistics	content knowledge	modelling competence
Persons per Item	54 - 60	175 – 232
Number of Items	37	46
EAP Reliability	0.776	0.711
Variance	0.733	0.335

Table 2: Results from the Rasch analyses for the NRW sample of the content knowledge and modelling competence test

Figure 2a shows that the item difficulties are distributed acceptably with slightly too many easy items which can be dropped in the main study. *Figure 2b* hints at a normal distribution of person abilities with a flatter slope at the left tail which are physics students who might potentially drop out due to a lack of modelling competence. The test is also slightly too easy for the NRW sample since the average person ability is above zero.

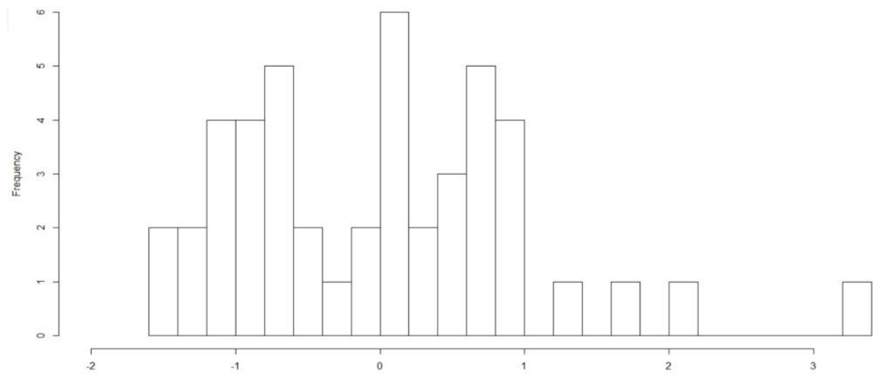

Figure 2a: Item Difficulty (x) vs. Item Frequency (y) of Modelling Competence Test

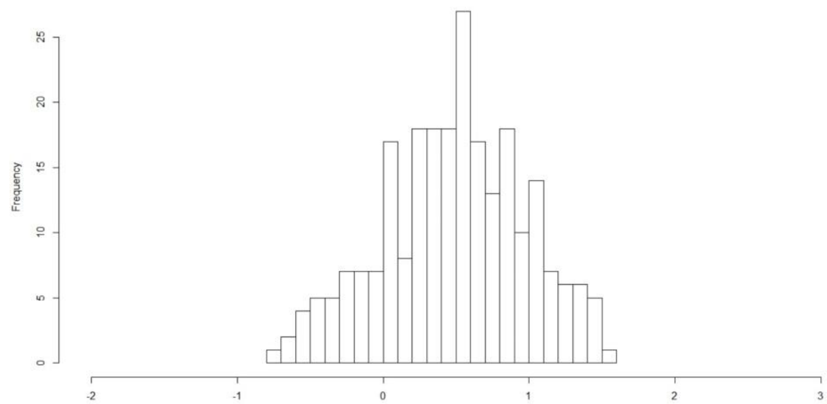

Figure 6b: Person Ability (x) vs. Number of Pers. (y) of Modelling Competence Test

By the time of the summer school all data from the pilot study will be surveyed and analyzed and the main study is yet to come.

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ANALYSIS OF MOTION IN ONE OR TWO DIMENSIONS – THE IMPACT OF SIMULATIONS AND FEEDBACK

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AN OVERVIEW – WHAT IS THIS PROJECT ABOUT?

The common 1-dimensional approach to Newtonian mechanics in 7th/8th grade includes a scalar velocity term ("speed") and detailed treatment of kinematics with speed and acceleration before addressing force issues (Tobias 2010). Contrary, in the 2-dimensional alternate approach[10] velocity is introduced as a vectorial quantity to avoid well-known problems (see theoretical framework). In this project, the introduction of Newtonian mechanics in 7th / 8th grade considering both approaches is examined – with consistent use of simulations combined with adaptive feedback methods. Therefore, a simulation-based learning environment, which is varied in the two factors *concept* and *feedback* (1D / 2D approach and instructional feedback / video feedback) was developed. Effects arising from these four possible particular combinations on learning outcomes can be investigated. The study is a contribution to research in adaptive feedback within multimedia systems, likewise the contribution to research in mechanics is partly replicative, as the two mechanical concepts have been directly compared in very few field studies in the past (e.g. Tobias 2010). However the present study offers subsequent considerations. The rearranged aspects in contrast to previous studies summarized below:

Condition	***Explanation of difference to previous studies***
learning environment	Prespecified to reduce the impact of teacher variable in contrast to previous studies
media	Consistent use of a sequence of simulations in contrast to a wide spectrum of different media like animations, simulations or modelling software in previous studies
feedback	Systematic use of feedback (cf. Hattie 2013), linked to simulations
curriculum	Adaption of local curriculum – particularly handling graphs and data, which was left out in previous studies (Niedersächsische Landesregierung, 2015)
context	Learning environment embedded in one central context (amusement park) and not several contexts as in previous studies

Table 1: Comparison of several conditions to previous studies

THEORETICAL FRAMEWORK

From the viewpoint of simplification, the **1D-approach** seems to be reasonable in terms of plainness. Motion in 1D is the easiest case of motion and technically consistent for lower secondary school. However, another aspect of simplification next to plainness is compatibility. In this light – especially when it comes to circular or rather curvilinear motion – the **2D-approach** can play of its

[10] Proposed by Jung, Reul und Schwedes, 1977, reprocessed in the past decade e. g. by Wilhelm 2005, Wiesner et. al. 2011.

strength. The decision between 1D and 2D swings between those poles. A spotlight on the approaches is given below.

Within the 1D-approach, naturally objects can only move forward or backward. This is simple but leads to no physical and hence no verbal distinction between "speed" and "velocity". The German term "Geschwindigkeit" in the proper sense means *velocity* but is also used as *speed* (cf. Boysen et. al. 2007). Furthermore, the nature of direction is only visible through positive or negative signs. This results in the need of odd "negative speeds" (="moving backwards") (cf. Wilhelm 2005). In addition, the connection between force and acceleration remains difficult.

In 2D-approach, motions are introduced in two directions (cf. Jung, Reul, Schwedes 1977, Tobias 2010). Velocity and speed are advisably used as different terms whereas velocity is represented through arrows. This ensures the compatibility with proper physical meaning in further lessons (circular motions, 10^{th} grade) or even university (curvilinear motion) – without being substantial too complex (Wiesner et. al. 2011).

Moreover the present 2D-approach springs from the acceptance "There is no free lunch". In physical terms, an impact (or rather a force) is always needed to change momentum and thus to add velocity considering m=const. The 2D-approach offers clarification that direction of force and added velocity[11] (or rather the direction of acceleration) is the same.

The rationale to use **simulations** in this subject area can be divided into inner reasons (emerge from topic) and outer reasons (emerge from general conditions of education policy). *Inner reasons* are: Dynamics and kinematics are about movement, and as long e.g. pictures are just static, simulations relieve to the working memory as they can show movement. Likewise movies and animations do so, but in comparison they offer less or no interaction as simulations can be manipulated in several ways that make it flexible and allow to try out things (cf. Eckhardt et. al. 2012) as well as to repeat incorrect or vague issues. Furthermore, simulations may combine multiple representations as required. In this case, these are model representations (vector arrows). *Outer reasons* are: Operating games, animations and complex applications on mobile devices is second nature to todays youth, so we assume a high familiarity in handling the simulations/tablet-computer-based learning environment and thus a high effectivity. Furthermore the spread of interactive whiteboards, tablet computers and touchscreens allows a lot more user interaction than years ago, as well as simulations offer a lot more possibilities, better performance and usability. So it is time to undertake a test drill!

As students explore motion with simulations without steady supervision on individual tablet-PCs, an instance to connect their handling of the simulations with the learning goals is required to ensure the learning progress. To this effect, we use two forms of automatic **feedback**. The importance of feedback was highly noted through Hattie's well-known meta-analysis. Feedback is considered "as information given about aspects of own achievement or own understanding" (translated, Hattie, 2013). Effective forms of feedback may be computer-assisted and directly related to learning goals (Hattie 2013). Assessment *during* the learning process is needed for generating information that can be used as feedback. Generating this information *at the end* of a unit would be ineffective for learning achievements

[11] „additional velocity" is used to point out that a velocity component is added through the impact (Tobias 2010). The term "acceleration" is avoided in the first approach.

(Black 2003). Feedback in the present learning environment is naturally computer-assisted and learning-goal orientated. It follows a set of multiple-choice questions[12] after each simulation. So the construction of feedback in the developed learning environments considers the aspects mentioned above as well as it is inspired by other projects of the workgroup (e. g. SAILS[13]). We distinguish between two forms of feedback: (1) instructional feedback (instruction to students how to handle simulation again to clarify the crucial aspect regarding the learning goal and the chosen answer option) and (2) video feedback (video of operated simulations to clarify the crucial aspect regarding the learning goals and the chosen answer option).

The **context** of the planned motion-unit is a trip to an amusement park. Thus the concepts of force and motion are to be explored with the help of rollercoasters, white-water rides, bumper cars and air hockey games. The **learning environment** is to be handled by a single student on an own tablet computer. It consists of a set of about 60 no-scroll HTML5 pages, about 15 with simulations embedded. These simulations are in-house developed using Unity3D-engine[14]. The remaining pages contain further texts or example calculations. After each simulation the mentioned assessment of its contents followed by feedback is attached to ensure the reaching of the learning goals. A self-contained learning environment is not the most authentic way to offer learning opportunities in a field study, but we do so because it is desired to keep the number of uncontrolled variables small – here the enormous influence of the teacher. Conducting a tablet-based learning environment has already been successful in other projects of the Hanoverian workgroup.

GOALS AND HYPOTHESIS

Research hypothesis we are planning to investigate are as follows:

- Students achieve better learning outcomes through the 2D-approach.
- The use of different forms of feedback has a particular influence on the learning outcomes of the students.
- Different forms of feedback influence learning outcomes when using 1D or 2D-approach.
- The learning outcomes using 1D or 2D approach differs according to preknowledge of the students.
- Associated aspects of investigations:
    1) Acceptance of simulations and learning environments
    2) Students operation with simulations

RESEARCH DESIGN AND METHODS

The study is designed as a field study in 7th / 8th grade in a 2x2 factorial design (see tab. 2). Two to three additional classes, which are not part of any interventions, serve for generation of reference

	1D-approach	2D-approach
Instructional Feedback	~ 60 – 80 students	~ 60 – 80 students
Video Feedback	~ 60 – 80 students	~ 60 – 80 students

Table 2: Factorial design

[12] i.a. to simplify automatic analysis
[13] www.sails-project.eu , 29.1.2016
[14] https://unity3d.com/, 29.1.2016

values and will only take part in the assessment of the preknowledge and learning outcomes. To approach the research questions, both qualitative and quantitative methods will be used. Questionnaires (partly multiple-choice) will be the main data source for a pre-, post- and follow-up test (3 months afterwards). These tests contain items of the force concept inventory FCI, established items used in previous investigations (Tobias 2010) as well as new constructed items (adapted to the curriculum). Questionnaires for pre- and post-test will not contain congruent items but interleaving items, because it is assumed that students have little preknowledge and surely a learning progression will be visible – therefore the complexity of the items has to be adjusted by adding/rejecting/changing items to offer comparable complexity. Along with all other student inputs, information about navigation within the learning environment will be stored in a central databank. This allows e.g. quantitative analysis of the extent to which students toggle between simulations and feedback.

Qualitative methods contain semi-structured interviews with selected students. In the course of this, students may solve brief tasks, handle a simulation or explain a represented physical issue. The analysis of data will be conducted as proposed by Mayring (2010) (framework of paraphrase, generalization, reduction) and put into deductively developed categories such as *self-initiated reference to simulations, self-initiated reference to feedback, use of velocity term*.

Outlook: Long-term follow up tests are envisaged beyond this particular study when students are in 10th / 11th grade and further kinematic and dynamic aspects are learned.

From participating at ESERA Summer School, I promise myself to receive input from different perspectives to develop suggestions for conducting the main study, to sharpen research questions and refine methods for analysis of especially qualitative data. Much of the input will be generated also in discussions about other projects.

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MODERN PHYSICS IN SECONDARY EDUCATION – CREATING A NEED FOR THEORETICAL EXPLANATION

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OUTLINE OF THE STUDY

The aim of secondary physics education is that students will experience the power of the physics way of describing the world, besides content knowledge. That is, to infer far reaching consequences from simple premises, which turn out to hold in the real world. This aim has proven hard to attain in many areas, but the theory of special relativity, a new topic in the Dutch secondary physics curriculum, is a promising choice to reach these ambitions (Dimitriadi & Halkia, 2012). The theory is based on two assumptions (postulates), that can be regarded as rather straightforward (Einstein, 1905). However, the implications of these assumptions are not straightforward at all, but are very abstract and counterintuitive (Scherr, Shaffer, & Vokos, 2001).

For students to gain conceptual understanding, the learning process should place them in such a position that they experience the need to extend their conceptual knowledge in a certain (scientific) direction (Lijse, 2010). To be able to create such a need, the physics content must be reconstructed for this specific educational purpose (Kattmann, Duit, Gropengiesser, & Komorek, 1996).

We want to identify how students reason with key insights of relativity theory. This study is embedded in a project to design a teaching approach for relativity in secondary education contributes to learning relativity as productive and convincing tools for reasoning.

LITERATURE REVIEW

Extensive searches in physics education journals yielded only a few studies on student understanding of special relativity. This research shows that the key insights of relativity theory are hard to comprehend, even at the university level. In a study by Pietrocola and Zylberzstajn (1999), first year undergraduate physics students did not use the principle of relativity when asked whether the (relativistic) speed of a train would influence physics processes. When the relativity postulate was used, students conclusions were contrary to relativity theory. In a study by Villani and Pacca (1987), physics students involved in a MSC or PHD programme, when asked to reason with the speed of light, answered half of questions in line with the theory of relativity. Students' explanations were not consistent with relativity, students showed a strong notion of absolute time and movement and regarded relativistic effects as only apparent. Scherr, Shaffer and Vokos (2001) also found that physics students have a strong belief in an absolute reference frame. Lorentz transformations were regarded as correction of signal travel time, leading to the conclusion that time dilation and the relativity of simultaneity is something that can be corrected for, rather than actual physical phenomena. Secondary education students (age 16) showed similar conceptual difficulties (age 16) (Dimitriadi & Halkia, 2012). This study also showed that students in secondary education can handle the abstract situations and can reason with relativistic concepts. However, student responses showed that they do not understand why they should use these concepts.

Extra tutorials on these basic principles lead to an improvement of both understanding and application of relativity theory. In successful tutorials students experienced the confrontation with a problematic situation and carried out the resolution themselves (Scherr, Shaffer, & Vokos, 2002). In secondary education, students do not master techniques to solve meaningful quantitative problems and they cannot resort to life world experiences.

RESEARCH QUESTION FIRST STUDY

We want to address these conceptual problems and enable student learning of relativity theory. We therefore want to identify these key insights and study spontaneous reasoning. These issues resulted in the following research questions:

- 1.1. What are key insights for learning relativity theory from disciplinary, historical and nature of science perspectives?
- 1.2. What spontaneous ideas do students have regarding key insights for learning relativity theory?

RESEARCH DESIGN AND METHODS

Concept Analysis

To identify key insights for learning relativity, we have to study scientific publications as well as educational material and curriculum documents. An in depth study of the concept content, enables us to identify required insights and reasoning steps that tend to remain implicit in scientific publications, but are essential for reconstructing the science content for education (Kattmann, Duit, Gropengiesser, & Komorek, 1996). We analysed secondary education physics text books with a section on special relativity (7 Dutch methods and one English method were used) and secondary education curriculum documents on special relativity (Dutch, International Baccalaureate and UK A-level). Concepts and contexts for learning relativity were selected. We derived the following key insights:

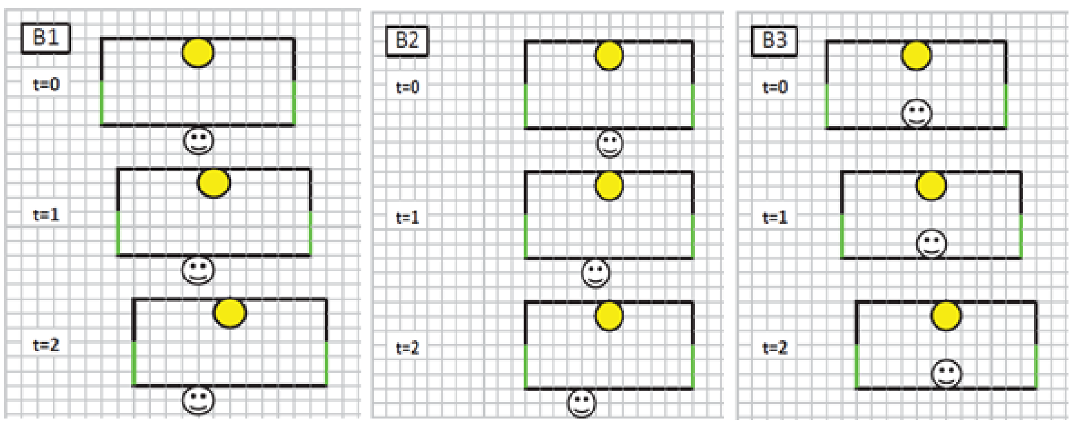
- To describe physical processes with respect to different reference frames;
- To make deductions from postulates and accept possible counter intuitive consequences;
- Quantities like mass, momentum, length, time interval, location and time have different values for observers in different reference frames;
- These findings change our ideas of space, time and energy;
- Newtonian physics as a limit of Special Relativity Theory.

Clinical Interviews

To explore students prior knowledge regarding these key insights, they are presented with open ended tasks, and spontaneous reasoning is explored in a Piagetian Clinical Interview. This way we can study student reasoning in depth, as well as follow up on interesting aspects of students' conceptions and test hypotheses regarding student thinking (Ginsburg, 1981).

We designed tasks around the first two key insights using the concept of the propagation of light and simultaneity. Reasoning with light is essential in relativity theory, and a classical reasoning pattern will yield very different results. Students were presented with the situation in which a light sensor will open a door when triggered by light from the light source in the room. The door and light sensor are located at two different ends of the room, with a light source in the middle. The observer has a relative motion with respect to the light source (situation B1 and B2), or the room as a whole, including observer has a relative motion to the background (situation B3). The light is switched on at t=0 and students are asked whether the doors open simultaneously, and whether the opening of the doors is observed simultaneously.

The situations and use of event diagrams are inspired by the probing questions presented by Scherr, Shaffer & Vokos (2001) and Dimitriadi & Halkia (2012). We introduced the combination of signal travel time to start an event and signal travel time to observe the event in the same question, because this distinction turned out to be problematic for students (Scherr, Shaffer, & Vokos, 2001).



PRELIMINARY FINDINGS

The situations have proven to be fruitful for students to reason with the propagation of light and simultaneity. Especially the use of event diagrams is productive. Although students were not forced to use a certain strategy, most students adopted the use of event diagrams at a certain point in their reasoning.

Most students use the idea that light has a constant (and fixed) speed. The reference frame in which light had this constant speed varied: most students chose either the light source, or the graph paper as a reference frame. All these students explained their answer with the use of an absolute space, which is in line with previous research (Scherr, Shaffer, & Vokos, 2001) (Posner, Strike, Hewson, & Gertzog, 1982). When asked about the speed of light students attribute an intrinsic speed to light ('light just moves with the speed of light, although one might observe it differently', 'the light will just move for itself, it does not matter whether the room moves or not') which is in line with spontaneous reasoning in kinematics where velocity is also viewed as something an object has, rather than something an object has relative to something else (Saltiel & Malgrange, 1980). Mixed reasoning, in which light moves with respect to the light source in one direction and with respect to the graph paper in the other direction, was also observed.

All students start out with light that moves relative to the light source. About half of them spontaneously change their answer and reasoning pattern. This usually is justified by the movement of the room. We expect that the student reasoning patterns, and why students change their reasoning patters, as found in this study, will support our design of an effective teaching approach in our next study.

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SESSION S: SCIENCE TEACHER EDUCATION

TEACHER TRAINING ON IMPLEMENTING A MODULE ON RRI AND NANOTECHNOLOGY

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OUTLINE OF THE FOCUS OF THE STUDY

Research shows that students' interest is attracted and they learn most effectively when scientific topics are up to date, based on current research and related to their everyday life (Ellis et al., 2005). Subjects relevant to cutting edge research and technology give students the opportunity to experience scientific knowledge in-the-making, deepen the understanding of Nature of Science and negotiate socio-scientific issues (Levinson, 2006). Nanoscience and Nanotechnology (NST) set up a scientific field appropriate to use to attain these objectives. Due to its scientific content and its attractive and yet controversial applications, NST can be a fertile field to promote students' scientific literacy but also to implement the framework of Responsible Research and Innovation (RRI), as recommended by an expert group on science education in a report to the European Commission (European Commission, 2015). The RRI framework consists of 6 key concepts: Engagement, Gender Equality, Science Education, Ethics, Open Access and Governance (European Commission, 2012).

However, all this required change ultimately relies on teachers, as the main factors of the renewal of Science Education (Osborne & Dillon, 2008), that is why their training on such issues is crucial. In other words, substantial research on professionalization of teachers in order to enact a more efficient use of innovative teaching strategies in introducing cutting edge research topics and RRI issues in science classes is needed.

In our research we focus on the way in which primary and secondary science teachers implement a given teaching module on NST and RRI issues in their classes with the support of expert school science teachers. In particular, we intend to investigate teachers' learning process towards the implementation of a module on NST and RRI issues under the supervision of expert teachers.

REVIEW OF RELEVANT LITERATURE

Research concerning professional development has widely adopted the concept of Pedagogical Content Knowledge (PCK; Shulman, 1987) as a means to investigate the growth pattern of teaching experience over time and to design efficient settings for teacher education (Loughran et al., 2008). Research has proven that teacher training courses have the potential to influence the development of PCK (Van Dijk & Kattmann 2007; Schneider & Plasman, 2011). As a result, numerous studies are focused on developing in-service teachers' PCK through professional training projects (e.g. Berliner, 2001; Appleton, 2008).

Regarding the subject of teachers' professional training, recently, research has taken a turn towards cutting edge scientific topics and their socio-scientific implications. Therefore, currently there are plenty of EU projects in Fp7 and Horizon 2020 frameworks that focus on RRI issues (e.g. IRRESISTIBLE, ENGAGING SCIENCE, RRI-TOOLS). At the same time science education research has particularly recognized the potential of NST in science teaching (Jones et al. 2013). A growing body of research on teachers' training in NST topics has been carried out, covering deficiencies regarding effective instructional materials and methods (e.g. Drane et al., 2009; Nichol & Hutchinson, 2010). Our research intends to make a further step in this direction, by inviting teachers to implement an NST module enriched with socio-scientific extensions, providing them with educational material and support from a network of expert teachers, research centers and science education researchers.

RESEARCH QUESTIONS

The main purpose of our study is to outline how teachers implement a teaching module on NST and RRI topics under the supervision of expert school science teachers. The detailed research questions are:

- A) To what extent are science teachers able to implement in their classrooms a module on NST and RRI topics under the supervision of expert teachers?
- B) What are science teachers' learning processes towards implementing a module on NST and RRI issues in their classrooms under the supervision of expert teachers?

METHODOLOGY AND RESEARCH DESIGN

The research framework of the thesis is the *Model of Educational Reconstruction* (MER; Duit et al., 2012), a model that aims to bring science content structure and educational concerns into a balance when developing teaching and learning sequences. As our research concerns teachers' professional development, we mostly use a variation of the MER, as introduced by Van Dijk and Kattmann (2007), that serves as a model for designing guidelines for the education of pre-service and in-service teachers. The Educational Reconstruction for Teacher Education (ERTE) model essentially incorporates aspects of the MER, as it interconnects the *Design of teacher education* with the *Research on teachers' PCK* and with MER components of *Learning environments' design*, *Empirical study of students' pre-conceptions* and *Analysis of the subject matter* (Figure 1).

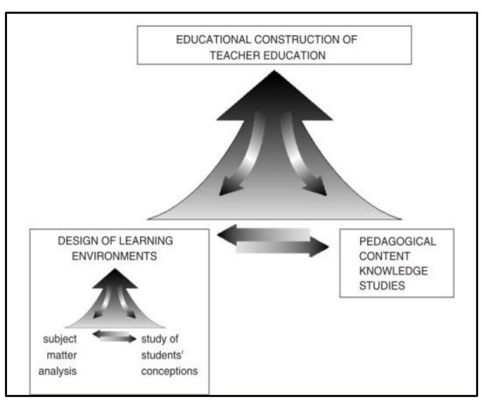

Figure 1: The Model of Educational Reconstruction for Teacher Education (ERTE)

Based on the Irresistible EU-Project (www.irresistible-project.eu) the research design is briefly as follows: In a first phase, 5 science teachers participating in a Community of Learners, along with science researchers, science education researchers and science communication experts, developed and implemented an inquiry-based teaching module on NST with emphasis on RRI issues (Alexopoulos et al., 2015). In a second phase, those 5 teachers (from now on "expert teachers") train further 15 teachers (2-4 teachers each), from both primary and secondary education, in implementing in their classrooms the NST module developed in the first phase. The final outcome of the module will be the development of a student-curated exhibition on nanoscience and RRI topics.

Teachers' training is in progress since last October, when a plenary kick-off meeting took place during which the main aspects of the module were presented. Thence, expert teachers meet, either face-to-face or on-line, with their teachers, in groups or singly. Up until now 5-7 meetings have been conducted, varying according to each expert teacher. In the first group meeting, they collectively reflected on teachers' needs regarding the module, which had been recorded by an open ended questionnaire and they co-organized the plan of the following meetings. In next 2-3 meetings the module was examined thoroughly, discussing alongside the fundamental concepts of NST, inquiry-based science education (IBSE) and RRI. During the latest meetings, which are held while teachers are implementing the module in their classrooms, expert teachers support them discussing and working out the difficulties teachers face, adapting the module to the students' needs and consulting them how to handle certain activities. In the following period, teachers, with the support of expert teachers, were involved in guiding their students in developing scientific exhibits. For that purpose an exhibits workshop held by science communication experts took place, in order to equip and orient teachers towards supporting their students during the exhibits development phase. As a corollary of the whole process, students presented their exhibits during the opening of two exhibitions hosted in the Eugenides Foundation and the Natural History Museum of the University of Crete, in April.

Data are collected through teachers' and expert teachers' pre- and post- questionnaires, audio/video recordings of on-line or face-to-face teachers' meetings, expert teachers' reports of the face-to-face meetings, interviews of teachers and expert teachers and by analyzing students' exhibits. Due to the explorative nature of the study methods of qualitative content analysis are applied (Mayring, 2015).

PRELIMINARY FINDINGS

Data so far indicate that teachers involved in the process with expectations and with the anguish that they will face difficulties addressing RRI issues, guiding students to develop exhibits and managing the module's scientific content. However, their main difficulties had to do with the module's adaptation to students' abilities and interests. These difficulties were addressed through cooperation with expert teachers and their colleagues and by modifying partly the module according to their students' needs, their personal interests and their leaders' directions. Data analysis is still in progress and more solid results will be available in the Summer School.

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THE IMPACT OF PROFESSIONAL DEVELOPMENT ON THE PRACTICE OF EXPERIENCED PHYSICAL SCIENCE TEACHERS TOPIC-SPECIFIC PCK IN STOICHIOMETRY

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OVERVIEW

Stoichiometry, which deals with the quantitative aspects of chemical reactions (Kolb, 1978), is considered by many teachers as a difficult topic for learners to grasp and difficult to teach appropriately (Gulacar, Overton, Bowmanc, & Fyneweverd, 2013). An understanding of stoichiometry is essential not only for solving stoichiometric problems (Furio, Azcona, & Guisasola, 2002; Gulacar *et al.*, 2013) but for conceptual understanding of other topics such as chemical equilibrium and acids and bases (Okanlawon, 2010). When teaching, teachers aim to ensure that students comprehend the content through a series of activities that provide an opportunity for learning (Shulman, 1987). Experienced teachers with the necessary content knowledge and pedagogical knowledge have the ability to blend content and pedagogy into a teachable form to help learners' understand the necessary stoichiometric concepts. Shulman (1987) defines this amalgam of content knowledge and pedagogical knowledge as pedagogical content knowledge, or PCK. Much of the research done on PCK has, according to Abell (2008), confirmed that teachers develop and use knowledge for teaching specific topics. This highlights the need to study teacher knowledge within topic-specific contexts. My study therefore investigates the development of experienced teachers' PCK in the topic of stoichiometry and the translation of this knowledge into classroom practice through participation in a lesson study. Lesson study is a collaborative process in which teachers plan a lesson together, teach the lesson and represents an example of a systemic and well articulated process for examining practice (Fernandez, 2002).

CONTEXT

My doctoral study is located within a project of the Marang Centre for Mathematics and Science Education that among other specific aims, aims to carry out large scale baseline assessments of teachers' PCK for specific topics in Physical Science in order to improve teaching and learning of these topics in classroom contexts. The particular focus of my study within this project is to investigate the interface between knowledge and practice.

PROBLEM STATEMENT

In first section of this synopsis the difficulties associated with the teaching of stoichiometry were highlighted. Evidence of learners' lack of proficiency in stoichiometry in South Africa has been highlighted with the inclusion of stoichiometric calculations in the final matriculation examinations over the past few years. The national reports on learner performance in these examinations (DBE, 2011, 2013) report that there is a lack of basic understanding of stoichiometric concepts and an inability to solve stoichiometric problems with recommendations that the topic be taught more thoroughly and the need for professional development of teachers. South Africa has a national policy that aims to assist teachers to enhance their professional competence and performance that recognises the need for teachers to reflectively develop their skills, content knowledge and pedagogical content knowledge (DoE, 2006). My study may provide insights into teacher professional development centred on the teacher through the creation of professional learning communities as a vehicle to develop teachers' knowledge and practice.

LITERATURE REVIEW

Pedagogical Content knowledge

The notion of PCK was introduced as one of the knowledge domains or categories of knowledge represented in the mind of the teacher required for effective teaching. Since the initial introduction of PCK various models have been developed by various researchers and all have been modified in different ways from Shulman's original proposal (Kind, 2009). Researchers have also used the construct and models in various studies to develop an understanding of teacher knowledge (Abell, 2008). Many studies have looked at the development of PCK and have focused on pre-service teachers in teacher preparation programs. There are however, limited studies on determining the relationship between the quality of teachers' PCK and their classroom practice (Abell, 2008).

Professional Development

In order to improve the teachers need to undergo professional development but many of the interventions sanctioned by the Department of Education are short-term with no theoretical basis and are ineffectual (Kriek & Grayson, 2009). Professional learning communities convened and centred around explicit discussions of the transformation of content knowledge for particular topics therefore offers the potential to improve teachers' conceptual understanding and understanding of learner errors (Brodie, 2011, 2014; Rollnick & Mavhunga, 2015). Developing practising teachers' PCK through involvement in professional learning communities has been described as a more sustainable and generative method for teacher development as it can allow teachers to focus on classroom practice (Brodie, 2011).

THEORETICAL FRAMEWORK

Teaching and learning is a complex process and is dilemma based (Gess-Newsome, 2015; Loughran, 2010) and teachers require a knowledge base to draw from when teaching (Corrigan, Gunstone, & Dillon, 2011). The lens through which teacher knowledge and teaching will be investigated within this study is topic-specific PCK. The topic-specific PCK model provides the mechanism for the transformation of content knowledge for a particular topic within the model of teacher professional knowledge and skill, or TPK&S that was drawn up at the PCK summit (Gess-Newsome, 2015; Rollnick & Mavhunga, 2015).

RESEARCH QUESTIONS

The research questions guiding my research are:

- How is the Topic-specific PCK of experienced practising teachers developed through participation in a lesson study?

- How and to what extent are the interactions in a professional learning community enacted in the lesson and teaching practice?

RESEARCH PARADIGM AND METHODOLOGY

I am approaching this study within a pragmatist research paradigm since the research design that will be employed is a mixed methods approach. A convergent parallel design in which quantitative data and qualitative data are collected separately and merged to understand the impact of a professional development activity on the development of topic-specific PCK and its enactment in classroom practice is being employed. The research strategy is a collective case study since multiple cases will be described and compared (Creswell, 2012). For this study data collection involved the use of instruments to measure the quality of participants' content knowledge and topic-specific PCK in stoichiometry, classroom observations and field notes, audiovisual data from planning meetings and lessons of the lesson study, teacher interviews and teacher questionnaires relating to beliefs and self-efficacy. Learner diagnostic tests were also administered to help inform the planning and improvement of the lesson.

ANALYSIS OF DATA

A sample of thirty experienced teachers completed the instruments during my Master's study. The results highlighted that teachers tend to focus on teaching stoichiometry algorithmically and guided the selection of teachers involved in the Lesson study. Data from the observations during the planning and/or teaching the lesson of the Lesson study have been transcribed and will be subjected to thematic analysis using the components of the topic-specific PCK. The pre-lesson and post-lesson, including the stimulated video recall interviews and final interviews will be transcribed and also subjected to thematic analysis. The frequency of topic-specific PCK episodes will be identified analysed and mapped to determine the integration of topic-specific PCK components and quality of these episodes (Park & Chen, 2012). During the video-stimulated recall interviews the teachers' responses in terms of their reasoning will be transcribed and the data pooled to develop a vignette of the episode of the enactment of topic-specific PCK in practice. Each classroom vignette will provide a detailed description of the interaction, the instructional strategy and/or representation used and the teachers thought process including their pedagogical reasoning. These various quantitative and qualitative data sources will be triangulated to corroborative evidence from the different data sources and the methods of data collection to determine the impact of the professional learning community of topic-specific PCK development and enactment of planned topic-specific PCK in practice (Creswell, 2012).

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A COMPARATIVE STUDY OF PRIMARY AND SECONDARY TEACHERS' UNDERSTANDING OF, AND PRACTICE IN, INQUIRY BASED SCIENCE EDUCATION

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STUDY FOCUS

Paul Nurse in his introduction to the Royal Society Science Policy report (2014) stresses that people need science for life so they can make informed choices. He states understanding of science comes mainly from schooling, so focussing on the 'what' and the 'how' is key in terms of ensuring science education in school is relevant. Unfortunately, the number of students choosing not to continue with science beyond compulsory age remains a concern. This lack of engagement being associated with the way that school science is taught (eg Archer et al, 2012; Jenkins & Pell, 2006; Osborn & Dillon, 2008; Rocard, 2007). The Rocard report (2007) highlights these issues and supports science education through an inquiry based approach. This is in the belief that it is not only more engaging but more effective than traditional teaching methods. The argument is that inquiry science is closer to the sort of science that students need for life and similar to the way real scientists work. This enhances student's understanding of science and science processes and likely to encourage more students to study science for longer. While the importance of inquiry science has been firmly established (eg Eurydice report 2011; McLoughlin, Finlayson, & Brady, 2013; PISA, 2012; Wellcome, 2011; & Wilson et al, 2010) there still appears little change in the way science is taught in most classrooms (Crawford, 2014).

My study focusses on primary KS2 teachers and their students, and secondary teachers in the early phases of secondary education, and their students. This transition phase has been identified as important for developing scientific identity (Archer et al, 2012) and well recognised as a point when attainment and attitudes towards science can dip (Galton, 2009). My research seeks to identify similarities and differences between the way primary teachers define and develop inquiry based science education (IBSE) with that of secondary teachers in England. By gaining an insight into the way science is taught coupled with the student's view, a greater understand of IBSE and its impact on student understanding of science and engagement with it can be explored. This will help to identify effective pedagogy and inform professional development programmes for initial teacher training and in-service teachers.

LITERATURE REVIEW

It is claimed that IBSE has the potential to increase student engagement and tackle what has been described as irrelevant and out-dated teaching approaches (McLoughlin, Finlayson, & Brady, 2013; Harrison, 2014). While there does not appear to be a single pedagogical method for effective IBSE, the principles are a blend of the philosophies of Jean Piaget (1936), Lev Vygotsky (1962, 1978), and David Ausubel (1968) and draw on a Constructivist approach to learning which also fosters self-regulated learning behaviours. Accepting that there is not a unified definition of 'inquiry' or agreement of the key inquiry skills or competences that should be developed, there is a consensus that the approaches are underpinned by focussing on 'how do we know' in order to enhance 'what is known' with an emphasis on student centred approaches (Osborn & Dillon, 2008; Rocard, 2007; National Research Council, 2000; Yeomans, 2011). My research will use Minner's classification (2010) which suggests that the term inquiry tends to address three distinct aspects of science education; 1) What scientists do; which includes planning and conducting investigations using scientific methods 2) How students learn; which includes mirroring the processes used by scientists to investigate problems or phenomenon and 3) Pedagogical approaches that teachers take; which is about the design of the curriculum that allow for things such as extended investigations

According to Saljo (1979) when students view learning as making meaning, they are more likely to take on greater responsibility for the construction of knowledge and take a proactive approach to initiating and regulating the construction process. In contrast, when they believe that learning is about transmitting an existing body of knowledge into their head, the control is external to themselves and they can exert little influence. It is argued that using an inquiry approach students are more likely to view learning as meaningful, relevant and interesting because the nature of science inquiry enables them to make decisions and actively co-construct new understanding. However, turning to the practice of secondary school science in England, there is a view that inquiry only refers to undertaking practical work and 'working scientifically' (National Curriculum, 2015). These practical sessions tend to focus on teacher-guided experiments that are often prescriptive in nature, with the teacher taking the leading role and the student's role reduced to presenting data that is then made sense of by the teacher (Abrahams & Miller, 2008). Unfortunately, this approach is considered unlikely to enhance conceptual understanding or develop a wide range of important inquiry skills including positive attitudes (Harrison, 2014). On the other hand, challenges facing primary teachers of science seem to relate to the diminished role of science within the primary curriculum as it no longer shares the same high status as English or Maths. This has led to a reduction in time allocated to teach it and a decline in status (Ofsted, 2013; Wellcome, 2013). Further compounding the teaching of primary science is that many teachers lack the subject knowledge or confidence to teach in an inquiry way (Crawford, 2014; Ofsted, 2013). Alternatively, the lack of inquiry approaches could be a lack of understanding of what IBSE means in terms of teacher' pedagogy and enactment, such as the degree of control over the process afforded to the learners.

RESEARCH DESIGN AND METHODS

My study is exploratory, taking an interpretative stance (Straus and Corbin, 1994: p273 in Cohen, Manion and Morrison, 2007), to appreciate and understand teaching and learning from contrasting perspectives. By examine what a purposive sample of teachers do, (and why), will help to determine typical characteristics of inquiry. Investigating how the teachers' planned 'decision-making opportunities' are experienced by their pupils, will give a unique opportunity to explore inquiry practice through the pupil experience. This is an under-explored aspect of IBSE research (Gray, 2015). Combined methods are used; surveying teachers to assess their conceptions and perceptions about their inquiry practice and ethnographic approaches of researcher observation (Bryman, 2008). Audio-recorded stimulated recall interviews (SRI), using video footage (Calderhead, 1981), will reflectively explore teacher and pupil participant justifications for their actions, using open-coding approach (Scott & Usher 2003). Issues of reliability and validity will be considered through the use of mixed, and combined-methods approach. The rationale is that it combines the strengths of qualitative research with the strengths of quantitative research and compensates for the weakness of each method in isolation (Punch, 2014 p303). My data collection methods will use observational studies, interviews (SRI) with teachers and pupils and questionnaires with teachers, to ascertain relationships or patterns between practice and personal belief (Lin, 1976 in Cohen, Manion & Morrison, 2007 p 141). This triangulated approach should reduce the chances of consistent findings being attributable to similarities of methods.

The aim of the interviews with teachers is to elicit descriptions of how inquiry is perceived and enacted. The SRI will be used to check the relevance of accounts of inquiry within the online survey and literature review. The choice of sample will include both primary and secondary teachers, taking an opportunistic approach.

It is stated that one way of controlling for reliability in interview schedules is to have a highly structured approach with the same format and sequence of words and questions for each respondent (Silverman, 1993 in Cohen, Manion & Morrison, 2007 p150). According to Oppenheim (1992, p147 in Cohen, Manion & Morrison, 2007) any changes in wording in questions in relation to attitudes and beliefs undermines the reliability because it stops being the same question for each respondent and can lead to error and bias. However, controlling the wording is also no guarantee of reliability or validity. Furthermore, a tight structure may misread the complexities associated with the area of study, so for this reason, a semi structured interview schedule will be used in the first instance, and open-probe questions in the SRI. A pilot study will be undertaken with teachers an one class, not engaged in the research project. Data from online survey during the summer term and will be available for presentation at ESERA summer school. Further data from lesson observation and interviews with teachers and their students will be undertaken in the autumn term.

By focusing on 'decision-making' within inquiry, I hope to uncover a key contributory factor that not only engage pupils to want to study science, but may also augment problem solving skills, such as those tested by PISA (2012). This will contribute to the debate around successful pedagogy and common barriers to the implementing science inquiry approaches within and across these two phases of education in England.

RESEARCH QUESTIONS

- What does the research literature indicate about the ways that primary and secondary teachers theorise and enact pedagogy to support inquiry skill development in science classrooms? (M.Phil)
- How do primary and secondary teachers differ in the ways they conceptualise inquiry skill teaching within 'Working Scientifically' (DfE 2013) (M.Phil)
- What do classroom observations and (reflective) stimulated recall discussions suggest about the contrasts in intended and enacted inquiry pedagogies? (Ph.D.)
- How does the 'experience' of learners' contrast with the intentions of inquiry teaching? (Ph.D.)

By attending the summer school, I hope to refine my data analysis methods by drawing on the expertise and interests of my peers and mentors. Together they will be able to help me recognise alternative perspectives on what is relevant or of interest. By hearing how others have approached their research I hope to contribute to their metacognition and reflective process.

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EXPLORING TEACHERS' INQUIRY PRACTICES AND STUDENTS' SCIENCE ACHIEVEMENT IN PHILIPPINE CLASSROOMS

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INTRODUCTION

Inquiry has been a major theme of K to 12 science curriculum reforms worldwide since the time of Dewey to the present (Wilson, Taylor, Kowalski, & Carlson, 2010). This is because inquiry has been considered to have a potential in promoting scientific literacy in classrooms (Flick & Lederman, 2004), which is the ultimate goal of science education (Lederman, 2004). There are three common perspectives on science inquiry. First, it is viewed as the process by which scientists use to develop scientific knowledge (Lederman, 2004). Second, it is viewed as classroom pedagogical approaches (DeBoer, 2004). Lastly, it is viewed as student learning outcomes (Flick & Lederman, 2004). Today, science inquiry in classrooms is advocated and expected yet surprisingly rare and enigmatic (Crawford, 2014). According to research, neither teachers nor students typically hold informed views of science inquiry (Schwartz et al., 2002; Lederman & Lederman, 2004; Lederman et al., 2014). As a result, most teachers have difficulty creating classroom environments that foster students' science inquiry skills (Lederman, 1992; McComas, 1998; Minstrell & van Zee, 2000; Lederman & Lederman, 2004). They tend to teach science as a collection of facts, principles, and concepts without explicitly instructing the processes by which scientific knowledge is generated and accepted. If teachers' understanding about science inquiry is not clear, they may inhibit students from being involved in inquiry activities that include questioning, designing and carrying out investigations, interpreting data, and developing explanations for the phenomena (Wallace & Kang, 2004).

It is unfortunate that the scenario described above was observed in science classrooms in the Philippines. To counter this, various professional development programs (e.g. seminar-workshops, lesson study) have been designed by teacher-training institutions to assist elementary and secondary school teachers shift from traditional to student-centered teaching approach. In fact, a large number of Filipino teachers are highly motivated to participate in regional and national professional development opportunities and have collaborated enthusiastically with science education specialists and university-based researchers to improve their own teaching. Although significant gains have been made through continuing professional development for teachers (NRC, 2000; Lotter, Harwood, & Bonner, 2007) traditional approach to teaching was still observed in many science classrooms in the Philippines (UP NISMED, DOST, & DepEd, 2010).

With this, recent efforts have been directed to improve science teaching and learning at the basic education in the Philippines. The Department of Education (DepEd) initiated a curriculum reform which resulted in the implementation of the Enhanced Basic Education (K to 12) Program. In this program, the new science curriculum is designed to be student-centered and inquiry-based, emphasizing the understanding and application of scientific knowledge, learning scientific inquiry skills, and developing and demonstrating scientific attitudes and beliefs (DepEd, 2013). In addition, organization of the curriculum has changed from previous curriculum in that concepts and skills are revisited at each grade level with increasing depth (spiral progression). Because of this reform, this study explores the nature of classroom instruction of teachers in the Philippines particularly their enactment of science inquiry practices as they implement the new K to 12 curriculum and how these practices relate to students' science learning. Although much empirical evidence in the literature support that inquiry-based instruction can lead to greater student achievement in science (Minner, Levy, & Century, 2010), little emphasis had been given on investigating the specific inquiry practices that teacher enact in classrooms and how these practices help to achieve this goal. Specifically, this study focuses on the following research questions:

- 1. What teaching practices implemented by teachers exhibit elements of science inquiry? What is the extent of implementation by teachers of these practices in classrooms?
- 2. What is the relationship between teachers' science inquiry practices and students' learning of chemistry content and science inquiry skills?

THEORETICAL FRAMEWORK

Most instructional models used in science teaching seem to provide a useful framework for inquiry in the classroom (Marshall, Horton, & Smart, 2009). It is acknowledged that every instructional model used to promote science inquiry in classrooms has its own merits. In this study, instructional models were used to draw common elements of science inquiry teaching in classrooms. These models were the BSCS 5E model (BSCS & IBM, 1989), guided-inquiry model (Magnusson, Palincsar, & Templin, 2004), essential features of inquiry (NRC, 2000), EIMA model (Schwarz & Gwekwerere, 2007), and scientific practices (NRC, 2012). These models were selected on the basis of the following points: (1) design for K to12 classroom settings, (2) have reference to a constructivist or socio-constructivist focus, and (3) more directly focused on student learning in an inquiry science environment.

Most of the key features of the aforementioned models suggest the commonalities in the following six major elements of science inquiry in the classroom: (1) engaging in questioning, (2) designing investigations, (3) collecting and organizing data, (4) analyzing and interpreting data, (5) formulating explanations and conclusion, and (6) communicating information. These six major elements of science inquiry were used as a framework for this study.

METHODS

A series of classroom observations were conducted to identify (1) specific teaching practices employed by teachers that show the 6 elements of science inquiry, and (2) the extent to which teachers implement these practices in classrooms. An observation instrument was developed which included 31 specific inquiry-teaching practices grouped into the 6 major elements of science inquiry. Observations were conducted in 12 grade 7 chemistry classes from 4 schools in Manila, Philippines. Ten classes were observed for 5 one-hour lessons, one class was observed for 4 one-hour lessons, and the remaining one class was observed for 3 one-hour lessons. Ten chemistry teachers were observed in this study. The total number of observations made was 57, over a period of 6 weeks. Pretest and posttest in chemistry were administered to determine the progress of student learning. Pretest was administered before completion of a chemistry unit and before the start of classroom observations. Posttest was administered after completion of a chemistry unit.

Observation data will be analyzed by determining the frequency of teaching implementation of each specific inquiry practice in classrooms. This was done by counting the number of ticks recorded in the instrument. Student test data will be analyzed by determining the growth score in chemistry using item response modeling (Rasch analysis). Hierarchical linear modeling (HLM) will be used to characterize the relationship between teachers' science inquiry practices and students' science learning.

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A CASE STUDY OF THE USE OF "ON THE FLY" INTERACTIONS BETWEEN THE TEACHER AND THE STUDENTS AS A MEANS OF FORMATIVE ASSESSMENT

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ABSTRACT

There is consensus about the importance of formatively assessing students' understanding during inquiry-based learning in science education. However, there is little research regarding informal formative assessment methods, despite teachers' claims that these are the most common in their teaching practice. This study focuses on what we call "on the fly interaction" in an effort to identify and document what can facilitate, or hinder, the effectiveness of this formative assessment method, the corresponding challenges that emerge in this context and possible ways to address them so as to really promote students' learning. For this purpose, implementations are applied in Physics classes at higher secondary schools by teachers who were trained on formative assessment methods. Lessons are videotaped and video data are coded in an effort to describe the various kinds of interactions that take place during assessment on the fly.

INTRODUCTION

Black & Wiliam (2009), suggest that, practice in a classroom is formative to the extent that evidence about student achievement is elicited, interpreted, and used by teachers, learners, or their peers, in order to make decisions about the next steps in instruction. Formative assessment can be (a) formal or planned, which focuses on obtaining information about student learning using specific tools; and (b) informal or interactive formative assessment, which takes place continuously in the learning environment, in any student–teacher interaction (Bell and Cowie, 2001). Whole class discussions are usually rich on what is called "On the fly" interaction between teacher and students. This interaction includes a lot of information that can be used formatively. We use the term "*On the fly" interaction as an assessment method* for assessment that occurs spontaneously during the course of a lesson when "teachable moments" arise in the classroom and teachers have to make inferences on a moment-by-moment basis (Heritage, 2007). In the case of on the fly interaction, no written record of the information is gathered.

The teacher's role is to pose questions and facilitate discussion that results in a consensus view acceptable to the classroom (Duschl, 1997). However, there is a number of challenges that teacher meet when trying to apply such an assessment method. Mastering informal assessment strategies is extremely complex, introducing significant challenges to the assumptions and methods underlying the current practice of the majority of science teachers.

For these reason, it is of great importance to investigate what facilitates effective informal formative assessment in science classrooms, what are the restrictions that appear and how teachers could be supported in order to improve their own practices. This particular study focuses on the following research questions:

- 1. What patterns can we identify in the interactions between the teacher and the students?
- 2. What factors seem to facilitate or impede teachers' attempt to guide students towards the inquiry learning goals using interactions on the fly?
    - a. What are the emergent factors that seem to afford productive teacher feedback?
    - B. What are the various types of missed opportunities (as identified in the rationale) encountered in the interactions on the fly; and what are the possible interpretations for why these opportunities were missed by the teacher?

METHOD

In order to address these questions through classroom based research, a learning environment focusing on the competence of *designing and implementing* investigations was implemented in two different occasions. The first implementation took place at a vocational school, in a class of twelve 15-16yo students. The second implementation took place in a Lyceum in two classes of 20 and 21 15-16yo students respectively. The instruction in both cases was undertaken by the physics teachers who both had more than 10 years of experience. Each implementation lasted ten to eleven 45min teaching periods and used the context of accelerating motion. "On the fly" formative assessment was applied during whole class discussions, where the teacher raised specific issues relevant to the experimental design, the experiment itself or interpretation of the results.

In all cases, the lessons were videotaped and those parts of the video that included interactions "on the fly" were identified and transcribed. Interactions between teachers and students are coded using the ESRU scheme (Ruiz-Pinto & Furtak, 2006). Specifically, the interactions were coded as either instances of E (elicit), S (students' response), R (recognize) or U (use). Research evidence suggests that completed ESRU cycles and iterations of complete ESRU cycles are indicative of productive interactions between the teacher and the students in the assessment dialogue framework. Drawing on this idea, I sought to identify instances in which the cycle happened to break and elaborated on the different reasons underlying this. Next, results from the analysis of the classroom dialogues from these two implementations are presented.

RESULTS

In the case of the first implementation we identified three instances of classroom dialogue that seemed consistent with the assessment method (i.e.., interactions on the fly). The coding of these dialogues revealed that the ESRU cycle was completed 41 times, while for 22 times it remained incomplete, either as ESR or ES. In a similar manner, during the second implementation we identified 6 instances of dialogue, which involved a total of 77 completed ESRU cycles and 130 broken ESRU cycles (table 1).

Variant of ESRU cycle	Frequency (1st Impl.)	Frequency (2nd Impl.)
Complete ESRU	41 (65%)	77 (37%)
Incomplete ESR or ES	22 (35%)	130 (63%)

Table 1: Complete and incomplete ESRU cycles.

Focusing on particular parts of the dialogue, in order to understand what has impeded teachers' attempt to guide students towards the inquiry learning goals using interactions on the fly. In many cases, the teacher chooses to utilize information that comes up during discussion only when this matches his/her priorities and specific objective s/he is pursuing at this particular moment, at the expense of alternative ideas and possible misconceptions that seem to exist. Throughout this paper we use the term "missed opportunities" to refer to these instances of either not utilizing contributions from students or not doing so in a productive manner. Consider the following excerpt from the whole class discussion, where the teacher tries to help students define the notion of the "environment" for an object in the context of dynamics, discussing about a small ball that she holds with her hand:

T: Are plants, sun, atmosphere part of the environment for this object?
S: No.
T: Why not?
S: Because we are not interested in whatever is outside.
T: Right…
[…]
T: What is the difference between ground and Earth?
S1: The Earth in general?
T: The Earth in general and the ground in particular?
S1: Yes, because the ground is in its(the object's) environment.
T: The Earth isn't in its environment?
S1: The Earth is outside.
S2: It (Earth) is natural environment.

In the above excerpt from the classroom dialogue we were able to identify 2 complete ESRU cycles. In these cases, the teacher asks students to elaborate more and express their thinking. At the same time, a crucial misconception like that the environment for an object is what is close to the object is not elaborated, despite the opportunities that emerged for initiating a discussion about this. Consequently, while coding shows that ESRU cycles are realized, at the same time valuable information remains unutilized. This finding is in line with Coffey's (2011) skepticism about the need to consider disciplinary substance when evaluating the discourse that takes place in the science learning environment.

	Type of missed opportunity	Example of the of missed opportunity	Freq.
1	The teacher neglects a potentially productive contribution made by the students, not directly related to the specific issue of discussion but directly connected to the topic under consideration more broadly.	The notion of action and reaction comes up but the teacher does not pay attention to it at that time; this idea becomes relevant to the discussion and there is evidence suggesting that students' misconceptions inhibit the discussion that follows.	8

2	Teacher’s statements derive from certain (usually hidden) presuppositions that might not be shared by the students.	The teacher assumes that students understand Earth as a massive object that causes measurable gravitational force. There are indications that this assumption is not always valid and it tends to perplex the discussion in certain ways.	7
3	Miscommunication between teacher and student	The students initially conceive of the term “environment” as referring to the spatial configuration (proximity) among objects. This goes unnoticed (or underestimated) by the teacher, causing much confusion.	6
4	Underestimation of students’ weaknesses on scientific methods	There was an opportunity for discussing random vs systematical error that was not utilized by the teacher; this could have led to a useful discussion consistent with the emphases of disciplinary knowledge in science.	6

Table 2: Typology of missed opportunities.

In addition to detecting and documenting missed opportunities, emphasis has also been given to the reduction of the various instances into a limited number of categories, which depict the main types of missed opportunities. The outcome of this process so far is shown in table 2. This table outlines the different types of missed opportunities and indicates their relative prevalence. It has to be noted that the data analysis process is still at an early stage and therefore the content of the table is refined as the process evolves. This could involve adjustment of the scope of the different categories of missed opportunities or reorganization of the groupings between them so as to better reflect commonalities but also distinctions between the different types of missed opportunities. In any case, it could be argued that this could be further explored to yield a typology of missed opportunities, which in turn, could help identify and document factors that tend to impede teachers’ attempt to employ “interactions on the fly” as a formative assessment method.

CONCLUSION

Data analysis so far suggests that teachers were able to apply the assessment method “on the fly interaction”, although to a rather limited extent. In addition they offer indications of certain patterns in the dialogue that takes place during these interactions. However, the method is very demanding both when it comes to recognizing students’ difficulties or misconceptions and, if teachers do so, to adapt their instruction according to students’ needs or pose the appropriate questions to promote students thinking and understanding. Thus, teachers need extensive training before they can be able to usefully engage with this formative assessment method in their practice. Scaffolding teachers’ formative assessment practices is an important, yet often underdeveloped, area of their initial teacher preparation (Buck et al. 2010).

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